# INTRODUCTION TO CHEMISTRY 1

## CHEMISTRY:

*"The branch of natural (physical) science which deals with the study of the composition, properties, structure, changes and the laws governing the changes that occur inside matter is called Chemistry".*

## Matter:

*Anything having mass and occupying space (volume) is known as Matter.*

There are three commonly known states of matter. According to latest information, there are four states of matter.

1. Solid
2. Liquid
3. Gas
4. Plasma (newly discovered fourth state of matter but not known commonly)

## Mass:

The quantity of matter present in a body is called mass. Its S.I. unit is kilogram.

$$1kg = 1000g \text{ or } 10^3 g$$
$$1g = 1000mg \text{ or } 10^3 mg$$
$$1kg = 1000000mg = 10^6 mg$$

## Weight:

The force by which the earth attracts a substance towards its centre is called the weight of the body.

**Unit:** Its S.I. unit is Newton.

## Volume:

The space occupied by any substance is known as volume.

The S.I. unit of volume is Cubic metre ($m^3$) or metre cube. Usually, cubic decimetre ($dm^3$) or cubic centimetre ($cm^3$) are used.

$$1dm^3 = 1 \text{ litre} = 1000ml = 1000cm^3$$

# HISTORY OF CHEMISTRY

## THE GREEK PERIOD:-

**Famous Greek philosophers**
**Aristotle (322 – 384 B.C.)**
**Plato (347 – 428 B.C.)**
**Democritus (357 – 460 B.C.)**

- They introduced the concept of elements, atoms and chemical reactions.
- They thought that matter was derived from four elements: **fire**, **air**, **water** and **earth**.
- These elements have properties of their own such as **dry**, **hot**, **cold** and **wet**.
- According to them: **fire** was hot and dry, **air** was hot, wet and dry, **water** was cold and wet while **earth** was cold and dry.

## THE ROMAN PERIOD:-

- They improved metallurgical processes and introduced enamelling of pottery. However, they developed little theoretical knowledge in this regard. Their works were all empirical.

# THE MUSLIM PERIOD: (600 – 1600 A.D.)

The Muslim period was from **600 to 1600 A.D.** in the history of Chemistry and is known as the period of **alchemy.**

## Jabir – Ibne – Haiyan (721 – 803 A.D.):

He is generally known as the **father of alchemy.**

**Achievements:**

i) He discovered white lead pigment.

ii) He also developed many laboratory apparatus.

iii) He also developed the methods for dyeing cloth.

iv) He also developed the methods for the extraction of metals from their ores.

v) He invented experimental methods for the preparation of Nitric acid ($HNO_3$) and Hydrochloric acid (HCl).

## Al Razi (862 – 930 A.D.):

Al Razi was a physician, chemist (formerly known as alchemist) and a philosopher.

**Achievements:**

i) Al – Razi prepared Ethyl alcohol by the fermentation of sugar.

ii) He was an expert surgeon and was the first to use opium as anaesthetic.

iii) He divided the substances into having living and non – living origins, which was later adopted by Berzellius, in 1806 to classify chemical compounds on the basis of their origins as organic and inorganic compounds.

## Al – Beruni (973 – 1048 A.D.):

He contributed in Physics, Metaphysics, Mathematics, Geography and History. In the field of Chemistry, he determined the **densities of different substances.**

## Ibne – Sina (980 – 1037 A.D.):

Ibne–Sina was famous for the contribution in the field of:

- Medicine
- Medicinal Chemistry
- Philosophy
- Mathematics
- Astronomy.

# THE MODERN PERIOD (1600 A.D. to ONWARD)

| NAME OF SCIENTISTS | | CONTRIBUTION IN CHEMISTRY |
|---|---|---|
| ROBERT BOYLE | (1627 – 1691) | He is known as the father of modern-Chemistry. He was the first scientist to put forward the idea that Chemistry should be regarded as a systematic investigation of nature with the sole aim of promoting knowledge. |
| J. BLACK | (1728 – 1799) | He discovered Carbon dioxide (CO$_2$). |
| J. PRIESTLY | (1733 – 1804) | He discovered Oxygen (O$_2$). Sulphur dioxide (SO$_2$) and Hydrogen chloride (HCl) gas. |
| SCHEELE | (1742 – 1786) | He discovered Chlorine gas (Cl$_2$). |
| CAVENDISH | (1731 – 1810) | He discovered Hydrogen gas (H$_2$). |
| LAVOISIER | (1743 – 1794) | He discovered that Oxygen is one fifth part of air. |
| JOHN DALTON | (1766 – 1844) | He gave the atomic theory of matter. He introduced the idea of atoms and molecules. He also gave the concept of atomic weight. |
| GAY – LUSSAC | (1778 – 1850) | He discovered a relationship between the mass and volume of a gas. |
| AVOGADRO | (1776 – 1856) | He determined the number of particles in one mole of substances and gave the relation between the number of molecules and their volume. |
| DULANG | (1785 – 1838) | He determined the relative atomic and molecular masses of many substances. |
| PETIT | (1741 – 1820) | He determined the relative atomic and molecular masses of many substances. |
| J. BERZELIUS | (1779-1848) | He introduced the symbols of elements based on single or double letters. |
| MENDELEEV | (1824 – 1907) | He described the periodic arrangement of the elements. |
| ARRHENIUS | (1859 – 1927) | He proposed the theory of ionization. |
| M. FARADAY | (1791 – 1867) | He stated the laws of electrolysis. |
| J.J. THOMSON | (1856 – 1940) | He discovered the electrons. |
| H. BECQUEREL | (1852 – 1908) | He discovered the phenomenon of Radioactivity. |
| MADAM CURIE | (1867 – 1934) | She made the discovery of Radium. |
| E. RUTHERFORD | (1891 – 1937) | He discovered the nucleus of an atom. |
| NEILS BOHR | (1885 – 1962) | He removed the weaknesses in Rutherford's atomic model and suggested an improved atomic model. |

## SIGNIFICANT REASONS TO STUDY CHEMISTRY (IMPORTANCE OF CHEMISTRY):

There are many reasons to study Chemistry. Few of them are given below:
- Chemistry is an intellectual enterprise, a way of explaining our material world.
- Chemistry enables us to design all sorts of materials, drugs to fight disease, pesticides to [illegible]
- Chemistry figures prominently in other fields, such as in Biology in the advancement of medicine.
- Chemistry has important practical application in the society. The development of life saving drugs is one and a complete list would touch upon most areas of modern Chemistry.

## EXAMPLES OF CHEMICAL SUBSTANCES USED IN DAILY LIFE:

**Chlorine:**
- It is used in treating water to kill pathogenic (disease causing) organisms.
- It is used in making Polyvinyl chloride (PVC) for the manufacture of plastic pipes.

**Fluorine:**
- Its compounds are used as pesticides and flame retardant.
- Its compound PTFE (Poly tetrafluoroethene), commonly known as **Teflon**, is used for making non-stick utensils.

## BRANCHES OF CHEMISTRY

### 1. ORGANIC CHEMISTRY:

The branch of Chemistry which deals with the study of Hydrocarbons and their derivatives is known as ***ORGANIC CHEMISTRY.***

***OR***

The branch of Chemistry which deals with the study of Carbon and its compounds (except $CO_2$, CO, carbonates, bicarbonates, cyanides.) is known as ***ORGANIC CHEMISTRY.***

*e.g.* Properties and preparation of Methane, Ethane, Ethene, Ethyne, Benzene, etc.

### 2. INORGANIC CHEMISTRY:

The branch of Chemistry which deals with the study of Chemistry of elements and their compounds, generally obtained from non – living organisms, i.e. from minerals is known as ***INORGANIC CHEMISTRY.***

***OR***

The branch of Chemistry which deals with the study of minerals and the elements (except Hydrocarbons and their derivatives) is known as ***INORGANIC CHEMISTRY.***

*e.g.* Properties and preparation of different elements from their minerals.

### 3. PHYSICAL CHEMISTRY:

The branch of Chemistry which deals with the laws and the principles governing the combination of atoms and molecules in chemical reactions and study of physical properties of matter is called ***PHYSICAL CHEMISTRY.***

*e.g.* HCl gas contains covalent bond while NaCl contains ionic bond, etc.



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**4. ANALYTICAL CHEMISTRY:**

The branch of Chemistry which deals with the study of the methods and techniques involved in determining the types, quality and quantity of various components (elements) in a given substance is known as *ANALYTICAL CHEMISTRY.*

*e.g.* Analysis of water gives an idea that $H_2O$ contains Hydrogen and Oxygen in the ratio of 2:1 by parts or 1:8 by mass.

**5. BIOCHEMISTRY:**

The branch of Chemistry which deals with the study of chemical reactions (metabolism) involved in living organisms i.e. plant and animal cells is known as *BIOCHEMISTRY.*

*e.g.* digestion of food in living things, action of medicines, etc.

**6. NUCLEAR CHEMISTRY:**

The branch of Chemistry which deals with the study of changes occurring in the nuclei of atoms, accompanied by the emission of invisible radiations is known as *NUCLEAR CHEMISTRY.*

*e.g.* emission of alpha ($\alpha$), beta ($\beta$) and gamma ($\gamma$) radiations.

**7. ENVIRONMENTAL CHEMISTRY:**

The branch of Chemistry which deals with the study of the interaction of chemical materials and their effects on the environment of animals and plants is known as ENVIRONMENTAL CHEMISTRY.

*e.g.* global warming can be reduced by planting more trees, etc.

**8. INDUSTRIAL OR APPLIED CHEMISTRY:**

The branch of Chemistry which deals with the study of different chemical processes involved in the chemical industries for the manufacturing of synthetic products is known as *INDUSTRIAL CHEMISTRY.*

*e.g.* glass, cement, paper, soda ash ($Na_2CO_3$), fertilizers, etc.

**9. POLYMERIC CHEMISTRY:**

The branch of Chemistry which deals with the study of polymerization and the products obtained through the process of polymerization is known as *POLYMERIC CHEMISTRY.*

*e.g.* Polyethene (plastic bags), Polyvinyl chloride (PVC), synthetic fibres, etc.

# THE SCIENTIFIC APPROACH IN CHEMISTRY

Science has developed through series of discoveries since a long time which started off as observed natural phenomenan which had to be explained. This was done by using scientific method in a systematic manner.

There are four main stages of scientific method:

1. Observation
2. Hypothesis
3. Theory
4. Scientific law or principle

## 1. OBSERVATION:

***Observation is a basic tool to elaborate a phenomenon. It varies from person to person and depends on the person's own skills and elaboration.***

### EXPLANATION:

Different people observe a phenomenon in different ways. Some of us observe something very critically to extract from it a new point. Observation of a thing is one of the scientific approaches in Chemistry.

## 2. HYPOTHESIS: (Trial idea):

***The explanation, obtained by the pondering of a scientist after observing a phenomenon which is still on a trial, is called Hypothesis.***

### EXPLANATION:

When a phenomenon is observed, a scientist ponders over it and carries out relevant experiments. He sieves through the data and arrives at a possible explanation for the nature of the phenomenon.

## 3. THEORY (Scientifically Acceptable Idea or Principle to Explain a Phenomenon):

***The Hypothesis, which is supported by a large number of different types of observations and experiments given by many scientists, is known as a Theory.***

### EXPLANATION:

The scientist conveys his hypothesis to other workers of the same fields for discussion and for further experimentation. When the hypothesis is supported by a large amount of different types of observation and experiments, then it becomes a theory i.e. scientifically acceptable idea or principle to explain a phenomenon. A good theory predicts new facts and unravels new relationship between naturally occurring phenomena.

## 4. SCIENTIFIC LAW OR PRINCIPLE:

***A theory, which is tested again and again and found to fit the facts and from which valid predictions may be made, is known as scientific law or principle.***

### EXPLANATION:

Science cherishes all forms of ideas and proposals. Even obsolete (outdated) ideas are kept as reference. It is said that there is no end to knowledge, so development in science too may have no limits.

# GENERAL CHEMISTRY

| Atomic no. | Name | Symbol | Valency | Atomic mass |
|---|---|---|---|---|
| 1 | Hydrogen | H | 1 | 1 amu |
| 2 | Helium | He | 0 | 4 amu |
| 3 | Lithium | Li | 1 | 7 amu |
| 4 | Beryllium | [illegible] | [illegible] | 9 amu |
| 5 | Boron | B | 3 | 11amu |
| 6 | Carbon | C | 4 | 12amu |
| 7 | Nitrogen | N | 3 | 14amu |
| 8 | Oxygen | O | 2 | 16amu |
| 9 | Fluorine | F | 1 | 19amu |
| 10 | Neon | Ne | 0 | 20amu |
| 11 | Sodium | Na | 1 | 23amu |
| 12 | Magnesium | Mg | 2 | 24amu |
| 13 | Aluminum | Al | 3 | 27amu |
| 14 | Silicon | Si | 4 | 28amu |
| 15 | Phosphorous | P | 3 | 31amu |
| 16 | Sulphur | S | 2 | 32amu |
| 17 | Chlorine | Cl | 1 | 35.5amu |
| 18 | Argon | Ar | 0 | 40amu |
| 19 | Potassium | K | 1 | 39amu |
| 20 | Calcium | Ca | 2 | 40amu |

# SYMBOLS OF FEW METALS

| Atomic no. | English Name | Latin/Greek Name | Symbol |
|---|---|---|---|
| 11 | Sodium | Natrium | Na |
| 19 | Potassium | Kalium | K |
| 26 | Iron | Ferrum | Fe |
| 29 | Copper | Cuprum | Cu |
| 47 | Silver | Argentum | Ag |
| 50 | Tin | Stannum | Sn |
| 51 | Antimony | Stibium | Sb |
| 74 | Tungsten | Wolfram | W |
| 79 | Gold | Aurum | Au |
| 80 | Mercury | Hydragyrum | Hg |
| 82 | Lead | Plumbum | Pb |

# EXERCISE

**1. Fill in the blanks:**

(i) The early Greeks believed that everything in the universe was made up of four elements **fire, air, water** and **earth.**

(ii) Al-Razi divided chemical substances on the basis of their origin as **living and non living.**

(iii) **Organic Chemistry** is the branch of Chemistry which deals with the study of carbon compounds.

(iv) Biochemistry is the backbone of **Medical Science.**

(v) PVC is the short name for a plastic, **Polyvinyl chloride.**

(vi) Oxygen was discovered by **J. Priestly.**

(vii) The best disinfectant is **Chlorine.**

(viii) The periodic arrangement was the result of **Mendeleev's** work.

**2. Write the answers of the following questions:**

(i) Write a note on the historical development of Chemistry with special mention to the contribution of Muslim scientists in the field of Chemistry.

**Ans: Answer on Page # 4**

(ii) Define Chemistry and describe its importance.

**Ans: Answer on Page #3 and 6.**

(iii) What important role does Chemistry play in the society?

**Ans: Answer on Page # 6.**

(iv) Name the different branches of Chemistry and define them.

**Ans: Answer on Page # 6 and 7.**

(v) What do you mean by scientific approach in Chemistry? How will you differentiate between hypothesis and theory?

**Ans: Answer on Page # 8.**

(vi) What is scientific law?

**Ans: Answer on Page # 8.**

SESSION 2016-2017

# CLASS-IX

# CHEMISTRY

## Chapter # 2

## LAWS OF CHEMICAL COMBINATIONS

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S.1. State and explain law of conservation of mass + landolt's experiment

S.2. State and explain law of constant composition + Berzellius experiment

S.3. State and explain [illegible] proportion.

S.4. State and explain law of Reciprocal proportion.

S.5. Define mole, molar mass and Avogadro's number + Numericals.

S.6. Define element, at least 10 names of elements with their symbols.

S.7. Define mixture and its types.

S.8. Define compound. At least 10 names of compound and their formulae.

S.9. Define Chemical formula and its types + Numerical.

S.10. Define reactants, products and chemical equation.

S.11. Define Chemical reaction and its types.

S.12. Define Mass. mass relationship + Numericals.

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# LAWS OF CHEMICAL COMBINATIONS 2

## LAWS OF CHEMICAL COMBINATION:

Chemistry deals with chemical reactions. Chemists had found that these changes are governed by some empirical laws known as the laws of chemical combination.

**These laws are:**

1. Law of conservation of mass (matter)
2. Law of constant composition OR Law of definite proportions
3. Law of multiple proportions
4. Law of reciprocal proportions

## 1. LAW OF CONSERVATION OF MASS:

### INTRODUCTION:

This law was given by Lavoisier in 1785. 6

### STATEMENT:

***Matter can neither be created nor destroyed during chemical change.***

It means that during a chemical reaction, the initial mass of the reactants is equ to the final mass of the products.

*OR*

*"There is no detectable gain or loss of mass in an ordinary chemical reaction*

### PRACTICAL VERIFICATION: (LANDOLT'S EXPERIMENT)

This law was verified by many experiments performed by **Landolt**. He German chemist. His most popular experiment is as follows.

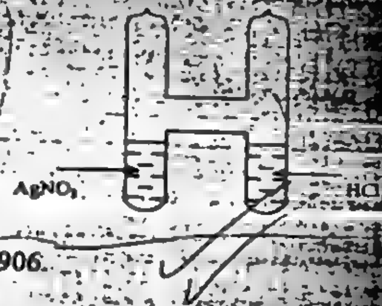
### EXPERIMENT:

He took an H-shaped tube having two limbs 'A' and 'B' as shown in the figur The limb 'A' was filled with $AgNO_3$ solution and the limb 'B' was filled with solution. The upper portions of the limbs were sealed to avoid the escaping of material. Both solutions are colourless. The H-shaped tube was weighed in verti position to avoid mixing of the solutions. The tube was then inverted and shaken to the two solutions. The following reaction took place.

$$AgNO_{3(aq)} + HCl_{(aq)} \longrightarrow \underset{\text{White ppt}}{AgCl_{(s)}} + HNO_{3(aq)}$$

Due to formation of white colored precipitates of AgCl, the entire tube became whi

The H-shaped tube was weighed again. It was observed that the total mass of the substances before the reaction was equal to the total mass of the substances after the reaction.




### CONVERSION OF MASS TO ENERGY:

Certain radioactive substances like Uranium undergo changes of such nature that very small quantity of mass is converted to energy by the following equation given by Albert Einstein in 1906.

$$E = mc^2$$

Where 'm' is the mass of the substance in gram and 'c' is the speed (velocity) light in cm / sec ($3 \times 10^{10}$ cm/sec). By putting these values in the above equation calculate the amount of energy obtained (unit is erg) by the conversion of mass. Finally, the law of conservation of mass can be stated as:

***"There is no detectable gain or loss of mass in a chemical reaction."***

# 2. LAW OF CONSTANT COMPOSITION:

## LAW OF DEFINITE PROPORTIONS (FIXED PROPORTIONS):

### INTRODUCTION:

This Law was given by a French chemist Louis Proust in 1799.

### STATEMENT:

***"Different samples of the same compound always contain the same elements combined together in the same proportion by mass".***

**Example:**

Water may be obtained from many sources (prepared in the laboratory, or obtained from rain, river or canal, etc.), but pure water always contains Hydrogen and Oxygen in the ratio 1:8 by mass.

$H_2O$
**2:16** [ **Atomic mass of H = 1 and O = 16**]
**1:8** **[parts by mass]**

### EXPERIMENTAL VERIFICATION: (Berzellius' Experiment).

The Swedish chemist, **J. Berzelius** performed an experiment to prove this law. 10g of Lead (Pb) was heated with 1.56g of Sulphur (S) to give 11.56g of Lead sulphide (PbS).

$$\underset{(10g)}{Pb} + \underset{(1.56g)}{S} \longrightarrow \underset{(11.56g)}{PbS}$$

This experiment was repeated by heating 18g of (Pb) and 1.56g of (S), then 11.56g of PbS was obtained and 8g of Pb remained unused.

$$\underset{(18g)}{Pb} + \underset{(1.56g)}{S} \longrightarrow \underset{(11.56g)}{PbS} + \underset{(8.0g)}{Pb}$$

**Conclusion:** It means that "Pb" and "S" always combine in the fixed ratio by mass.

# 3. LAW OF MULTIPLE PROPORTIONS:

### INTRODUCTION:

This Law was given by an English scientist **John Dalton in 1803.**

### STATEMENT:

***"If two elements combine to form more than one compound, the mass of one element is fixed while the mass of other element is in the ratio of small whole numbers or some multiple of it".***

**Example (i)**

Carbon (C) and Oxygen (O) combine to form two compounds CO and $CO_2$.

| COMPOUND | Mass of Carbon (C) | Mass of Oxygen (O) | Ratio of (O) |
|---|---|---|---|
| Carbon monoxide CO | 12 | 16 | 1 |
| Carbon dioxide $CO_2$ | 12 | 32 | 2 |

It means that 12g of (C) combines with 16g of (O) in CO and 32g of (O) in $CO_2$. Hence the ratio of (O) is 16:32 or 1:2 which is simple multiple ratio.

**Example (ii)**

Hydrogen (H) and Oxygen (O) combine to form two compounds Water ($H_2O$) and Hydrogen peroxide ($H_2O_2$).

| COMPOUND | Mass of Hydrogen (H) | Mass of oxygen (O) | Ratio of (O) |
|---|---|---|---|
| Water $H_2O$ | 2 | 16 | 1 |
| Hydrogen Peroxide $H_2O_2$ | 2 | 32 | 2 |

It means that 2g of (H) combines with 16g of (O) in $H_2O$ and 32g of (O) in $H_2O_2$. Hence the ratio of (O) is 16:32 or 1:2 which is a simple multiple ratio.

## 4. LAW OF RECIPROCAL PROPORTION:

### INTRODUCTION:

This Law was given by Richter in 1792-94.

### STATEMENT:

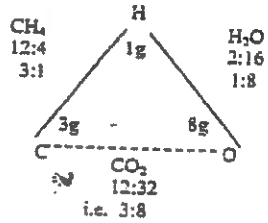
*"When two different elements separately combine with the fixed mass of third element, the proportions in which they combine with one another shall be either in the ~~simple~~ ratio or some multiple of it".*

Example (3)

'C', 'H' and 'O' combine separately to form $CH_4$, $H_2O$ and $CO_2$.

| | | | |
|---|---|---|---|
| Methane $CH_4$ | Mass of C 12 | Mass of H 4 | Ratio of H : C 4:12 or 1:3 |
| Water $H_2O$ | Mass of H 2 | Mass of O 16 | Ratio of H : O 2:16 or 1:8 |
| Carbon dioxide $CO_2$ | Mass of C 12 | Mass of O 32 | Ratio of C : O 12:32 or 3:8 |

It means that in $CH_4$, 1g 'H' combines with 3g 'C'. In $H_2O$ 1g 'H' combines with 8g 'O' while in $CO_2$, the ratio of 'C' and 'O' is 3:8 which is according to the law of Reciprocal proportions.




### ATOMIC NUMBER:

*"The number of protons present in the nucleus of an atom of an element is called atomic number".*

It is denoted by "Z".

The number of proton can be used for the identification of an element.

*e.g.* the atomic number of H = 1, C = 6, N = 7, O = 8, etc.

### MASS NUMBER:

*"The sum of number of protons and neutrons present in the nucleus of an atom of an element is called mass number".*

It is denoted by "A". Its unit is a.m.u.

*e.g.* mass number of H = 1, O = 16, Mg = 24, S = 32, Ca = 40, etc.

### ATOMIC MASS:

*"The sum of the average masses of natural mixture of the isotopes of an element which is compared to 1/12 part of C-12 is called the atomic mass of an element."*

It is denoted by "A". Its unit is a.m.u. (atomic mass unit).

*e.g.* atomic mass of H = 1, O = 16, Mg = 24, S = 32, Ca = 40, etc.

Two isotopes of Chlorine have been found: $_{17}X^{35}$ % = 75, $_{17}X^{37}$ % = 25. Calculate the average atomic mass of chlorine.

$$75 = \frac{Average\ \ mass}{35} x\,100$$

$$\left[\frac{75\ x\ 35}{100}\right] + \left[\frac{25\ x\ 37}{100}\right]$$

$$26.25 \div 9.25$$

$$35.5\ amu$$

## SYMBOL:

The representation of the full name of an element is called its symbol.

*e.g.* H = Hydrogen, C = Carbon, Na = Sodium, etc.

## CHEMICAL EQUATION:

... reactants and products through symbols and formulae is called chemical equation.

*e.g.* Carbon reacts with Oxygen to form Carbon dioxide

$$C + O_2 \rightarrow CO_2$$

## FORMULA:

The representation of the full name of a compound is called its formula.

*e.g.* NaCl = Sodium chloride, $CaCO_3$ = Calcium carbonate, etc.

## TYPES OF FORMULA:

### 1. EMPIRICAL FORMULA (E.F.) OR SIMPLEST FORMULA:

*"The formula which represents the simplest ratio of the atoms of different elements as well as relative number of atoms in a molecule of a compound is called empirical formula".*

### 2. MOLECULAR FORMULA:

*"The formula which represents the actual or exact number of atoms of different elements in a molecule of a compound is called molecular formula".*

| Compound | Empirical Formula | Molecular Formula |
|---|---|---|
| Benzene | CH | $C_6H_6$ |
| Ethyne | CH | $C_2H_2$ |
| Glucose | $CH_2O$ | $C_6H_{12}O_6$ |
| Acetic acid ($CH_3COOH$) | $CH_2O$ | $C_2H_4O_2$ |
| Water | $H_2O$ | $H_2O$ |

*The empirical and molecular formulae of inorganic compounds are same.*

**Relationship between Molecular and Empirical Formula:**

Molecular Formula = n x Empirical Formula

$$\text{Therefore} \quad n = \frac{\text{Molecular Formula mass}}{\text{Empirical Formula mass}}$$

## • MOLECULAR FORMULA MASS OR MOLECULAR MASS:

*"The sum of atomic masses of elements which are present in a molecule of a compound is called Molecular Formula Mass (Molecular Mass)".*

| Compound | Molecular Formula | Molecular Mass |
|---|---|---|
| Carbon dioxide | $CO_2$ | 12 + 2 (16) = 12 + 32 = 44 |
| Water | $H_2O$ | 2 (1) +16 = 2 + 16 = 18 |
| Glucose | $C_6H_{12}O_6$ | 6 (12) + 12 (1) + 6 (16) = 72 +12 + 96 = 180 |

## FORMULA MASS:

*"The sum of atomic masses of elements which are present in a formula unit of a compound is called Formula Mass."*

**NOTE:** **Molecular formula mass (molecular mass)** is used for covalent compounds while **formula mass** is used for ionic compounds.

## MOLAR MASS:

*"The mass of one mole of any substance (element/compound) which is expressed in gram is called the Molar Mass of a substance."*

**Atomic mass of C = 12.0 a.m.u. = 12.0g.**
**Molecular mass of $NH_3$ = 17.0 a.m.u. = 17.0g.**
**Formula mass of NaCl = 58.5 a.m.u. = 58.5g.**

## MOLE:

*"The atomic or molecular mass of an element. molecular mass or formula mass of a compound ...*

It is also defined as one mole of a substance contains $6.02 \times 10^{23}$ particles.
It is denoted by ***n***. Its unit is ***mol***.
The term Mole is used to measure the amount of a substance (element on compound) in grams.

### Examples:

**Atomic mass of C = 12.0 a.m.u. = 12.0g = 1 mole**
**Molecular mass of $NH_3$ = 17.0 a.m.u. = 17.0g = 1 mole**
**Formula mass of NaCl = 58.5 a.m.u. = 58.5g = 1 mole**

## AVOGADRO'S NUMBER ($N_A$):

***One mole of any substance contains $6.02 \times 10^{23}$ particles. This constant number is called Avogadro's number.***

**It is denoted by $N_A$.**

1 mole of any substance $= 6.02 \times 10^{23}$ particles (atoms, molecules or ions)

It is used to

### Atomic Form:

**1 mole of C = 12g = $6.02 \times 10^{23}$ atoms**

(i) Uses

### Molecular Form:

**1 mole of $H_2O$ = 18g = $6.02 \times 10^{23}$ molecules**

### Ionic Form:

**1 mole of $Na^+$ = 23g = $6.02 \times 10^{23}$ ions**
**1 mole of $Cl^-$ = 35.5g = $6.02 \times 10^{23}$ ions**

## CHEMICAL REACTION OR CHEMICAL CHANGE:

***The conversion of reactants to products through chemical change is called chemical reaction.***

*OR*

***A chemical reaction is that change in which the chemical composition of a substance is altered.***

1. $4Fe + 3O_2 \longrightarrow 2Fe_2O_3$
2. $2CO + O_2 \longrightarrow 2CO_2$

## REACTANTS:

***Those substances in which chemical change occurs and their chemical composition is changed are called Reactants.***

## PRODUCTS:

***The new substances which are formed from the reactants after the chemical change are called Products.***

*e.g.* milk changes into curd. In this reaction, milk is the reactant while curd is the product.

## TYPES OF CHEMICAL REACTION:

Chemical reactions can be divided into five different types:

i) Decomposition reactions
ii) Addition reactions (combination reactions)
iii) Single displacement reactions
iv) Double displacement reactions
v) Combustion reactions

## 1. DECOMPOSITION REACTION:

***When a single compound is heated in the absence of air, it splits into its simpler components. This reaction is called decomposition.***

Note: decomposition reactions are examples of endothermic reactions.

**Example# 1** $\underset{\text{Calcium carbonate}}{CaCO_{3(s)}} \xrightarrow{\text{Heat}} \underset{\text{Calcium oxide}}{CaO_{(s)}} + \underset{\text{Carbon dioxide}}{CO_{2(g)}}$

In this reaction, Calcium carbonate, on heating, gives Calcium oxide and Carbon dioxide gas.

**Example# 2** $\underset{\text{Potassium chlorate}}{2KClO_{3(s)}} \xrightarrow{\text{Heat}} \underset{\text{Potassium chloride}}{2KCl_{(s)}} + \underset{\text{Oxygen gas}}{3O_{2(g)}}$

In this reaction, Potassium chlorate on heating gives Potassium chloride and Oxygen gas.

## 2. ADDITION REACTION (COMBINATION REACTION):

***When two or more substances combine, a single compound is formed. This reaction is called addition reaction.***

Note: addition reactions are examples of exothermic reactions.

**Example# 1** $\underset{\text{Calcium oxide}}{CaO_{(s)}} + \underset{\text{Carbon dioxide}}{CO_{2(g)}} \longrightarrow \underset{\text{Calcium carbonate}}{CaCO_{3(s)}}$

In this reaction, Calcium oxide and Carbon dioxide are added to give Calcium carbonate.

**Example# 2** $\underset{\text{Sodium}}{2Na_{(s)}} + \underset{\text{Chlorine gas}}{Cl_{2(g)}} \longrightarrow \underset{\text{Sodium chloride}}{2NaCl_{(s)}}$

In this reaction, Sodium and Chlorine gas are added to give Sodium chloride.

## 3. SINGLE DISPLACEMENT OR SINGLE REPLACEMENT REACTION:

***"Displacement reaction is that reaction in which one atom or group of atoms of a compound is replaced by another atom or group of atoms".***

Note: single displacement reactions are examples of exothermic reactions.

**Example# 1** $\underset{\text{Zinc}}{Zn_{(s)}} + \underset{\text{Hydrochloric acid}}{2HCl_{(aq)}} \longrightarrow \underset{\text{Zinc chloride}}{ZnCl_{2(s)}} + \underset{\text{Hydrogen gas}}{H_{2(g)}}$

In this reaction, 'H' of 'HCl' is displaced by 'Zn'.

**Example# 2** $\underset{\text{Chlorine gas}}{Cl_{2(g)}} + \underset{\text{Potassium bromide}}{2KBr_{(aq)}} \longrightarrow \underset{\text{Potassium chloride}}{2KCl_{(aq)}} + \underset{\text{Bromine gas}}{Br_{2(g)}}$

In this reaction, 'Br' of 'KBr' is displaced by 'Cl'.

## 4. DOUBLE DISPLACEMENT REACTION:

***In double displacement reaction, the two compounds exchange their ions or radicals and then new compounds are formed.***

**Note:** double displacement reactions are examples of exothermic reactions.

**Example# 1**

$$NaCl_{(aq)} + AgNO_{3(aq)} \longrightarrow NaNO_{3(aq)} + AgCl_{(s)}$$

(white ppt)

**Example# 2**

$$\underset{\text{Calcium chloride}}{CaCl_{2(aq)}} + \underset{\text{Sodium carbonate}}{Na_2CO_{3(aq)}} \longrightarrow \underset{\text{Sodium chloride}}{2NaCl_{(aq)}} + \underset{\text{Calcium carbonate White ppt.}}{CaCO_{3(s)}}$$

## 5. COMBUSTION REACTION:

***When a compound burns in presence of air (oxygen), $CO_2$ and $H_2O$ are formed while heat (energy) is released.***

In other words, substances react with Oxygen (free oxygen or oxygen of air) to produce heat energy and flame.

**Example# 1**

$$\underset{\text{Methane}}{CH_{4(g)}} + \underset{\text{Oxygen}}{2O_{2(g)}} \longrightarrow \underset{\text{Carbon dioxide}}{CO_{2(g)}} + \underset{\text{Water}}{2H_2O_{(g)}} + \underset{\text{Heat}}{\Delta H}$$

In this reaction, methane is burnt with oxygen to form carbon dioxide along with the evolution of heat and flame.

**Example# 2**

$$\underset{\text{Carbon}}{C_{(s)}} + \underset{\text{Oxygen}}{O_{2(g)}} \longrightarrow \underset{\text{Carbon dioxide}}{CO_{2(g)}} + \underset{\text{Heat}}{\Delta H}$$

In this reaction, Carbon is burnt with oxygen to form Carbon dioxide along with evolution of heat and flame.

## INTERCONVERSION OF MASS AND MOLE:

$$\text{Number of moles} = n = \frac{\text{Mass of substance (gram)}}{\text{Molar mass}}$$

$$\text{Mass of substance} = n = \text{Number of moles} \times \text{Molar mass}$$

**PROBLEM#1 Calculate the number of moles in 100g of Carbon dioxide.**

**Data:**

Number of moles of $CO_2 = n = ?$

Given mass of $CO_2 = 100g$

Molar mass of $CO_2 = 44$ g

**Solution:**

$$\text{Number of moles of } CO_2 = n = \frac{\text{Mass of } CO_2 \text{ (g)}}{\text{Molar mass of } CO_2 \text{ (g)}}$$

$$n = \frac{100}{44}$$

**Number of moles of $CO_2$ = 2.27mol.**

**PROBLEM# 2:**

**Calculate the number of moles in 50g of sodium (Na).**

**Data:**

Number of moles of Na = ?

Given mass of Na = 50g

Molar mass of Na $= 23g$

**Solution:**

$$\text{Number of moles of Na} = \frac{\text{Mass of Na (g)}}{\text{Molar mass of Na (g)}}$$

$$= \frac{--}{23}$$

**Number of moles of Na = 2.173 mol .**

**PROBLEM# 3**

**What is the mass of 10 moles of Aluminium (Al)?**

**FORMULA:** Mass of substance = Number of moles x Molar mass

**Data:**

Mass of substance = ?

Given number of moles of Al = 10 mol

Molar mass of Al = 27 g

Mass of Al = Mole x Molar mass of Al

$= 10 \times 27$

**Mass of Al = 270 g .**

**PROBLEM# 4**

**What is the mass of 20moles of $CO_2$?**

**Data:**

Mass of substance = ?

Given number of moles of $CO_2$ = 20 mol

Molar mass of $CO_2$ = 44 g

**Solution:**

Mass of $CO_2$ = Number of moles of $CO_2$ x Molar mass of $CO_2$

$= 20 \times 44$

**Mass of $CO_2$ = 880 g .**

**PROBLEM# 5:**

**Calculate the number of atoms in 10 g of Aluminium (Al).**

**Method#1**

**Solution:**..

1 mole of Al $= 27\text{ g} = 6.02 \times 10^{23}$ atoms.

This shows that,

27 g of Al contains $= 6.02 \times 10^{23}$ atoms.

$$\text{1 g of Al contains} = \frac{6.02 \times 10^{23}}{27\text{ g}}$$

$$\text{10 g of Al contains} = \frac{6.02 \times 10^{23}}{27\text{ g}} x10 = 2.23 \times 10^{23} \text{ atoms}$$

**Number of atoms of Al = $2.23 \times 10^{23}$ atoms.**

**Method# 2**

**Solution:**

$$\text{Number of atoms} = \frac{N_A \times \text{Mass of substance (g)}}{\text{Molar mass}}$$

$$\text{Number of atoms of Al} = \frac{6.02 \times 10^{23} \times 10\text{ g}}{27\text{ g}}$$

**Number of atoms of Al = $2.23 \times 10^{23}$ atoms .**

**PROBLEM# 6:**

**Calculate the numbers of molecules in 50 g of $CO_2$.**

**Solution:**

$$\text{Number of molecules} = \frac{N_A \times \text{Mass of substance (g)}}{\text{Molar mass}}$$

$$\text{Number of molecules of } CO_2 = \frac{6.02 \times 10^{23} \times 50\text{ g}}{44\text{ g}}$$

Number of molecules of $CO_2$ = 6.841 x $10^{23}$

**PROBLEM# 7:**

**Calculate the mass of one atom of 'S' in grams.**

**Solution:**

$$\text{Mass of one atom} = \frac{\text{Molar mass}}{N_A}$$

$$\text{Mass of one 'S' atom} = \frac{32\text{ g}}{6.02 \times 10^{23}\text{ g}}$$

**Mass of one 'S' atom = $5.31 \times 10^{-23}$ g.**

**PROBLEM# 8:**

**Calculate the mass of one molecule of $CO_2$ in grams.**

**Solution:**

Molar mass of $CO_2$ = 44 g

1 mole of $CO_2$ = 44g = $6.02 \times 10^{23}$ molecules

This indicates that

$6.02 \times 10^{23}$ molecules of $CO_2$ = 44 g

$$1 \text{ molecule of } CO_2 = \frac{44\text{ g}}{6.02 \times 10^{23}}$$

**Mass of one molecule of $CO_2$ = $7.308 \times 10^{-23}$ g.**

## CHEMICAL EQUATION:

***The representation of a whole chemical reaction (reactants and products) through symbols and formulae is called chemical equation.***

*e.g.* Carbon reacts with Oxygen to form Carbon dioxide.

i) $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$  ii) $CaCl_{2(aq)} + Na_2CO_{3(aq)} \rightarrow 2NaCl_{(aq)} + CaCO_{3(s)}$

(s) *Solids*, (l) *Liquids*, (g) *gas*, (aq) *aqueous solution* are called state symbols of reactants and products in a chemical equation.

## POINTS TO REMEMBER:

1. ***Reactants*** are on the ***left hand side*** of the reaction and ***products*** are on the ***right hand side*** of the reaction.
2. ***Balancing of Equation*** is done by ***coefficients***.
3. Equation 'ii' indicates that $CaCl_2$ is ***dissolved in water*** to prepare an *Aqueous solution*.
4. ***Delta*** Δ over an arrow indicates that reactants are ***heated*** to give products.

## BALANCED CHEMICAL EQUATION:

Balanced chemical equation gives the following information:

i) The nature of reactants and products.

ii) The relative number of moles of each reactants and products.

## RULES FOR BALANCING OF CHEMICAL EQUATION:

i) Write the given formulae of all the reactants on the left hand side and the formulae of the products on the right hand side of an equation.

ii) Mention the number of atoms on both sides of the equation.

iii) If the number of atoms appears more on one side than the other, balance the equation by inspection method ... efficient so as to make the number of atoms, same on both sides of the equation.

iv) The covalent molecules of Hydrogen, Oxygen, Nitrogen and Chlorine exist as di-atomic molecules eg. $H_2$, $O_2$, $N_2$ and $Cl_2$, rather than isolated atoms, hence we must write them as such in chemical equation.

v) Finally, check the balanced equation, to be sure that the number and kinds of atoms are the same on both sides of the equation.

### Balance The Following Equations By Inspection Method:

1. $KClO_{3(s)} \longrightarrow KCl_{(s)} + O_{2(g)}$
2. $H_{2(g)} + O_{2(g)} \longrightarrow H_2O_{(l)}$
3. $CH_{4(g)} + O_{2(g)} \longrightarrow CO_{2(g)} + H_2O_{(g)}$
4. $NH_{3\,(g)} + O_{2\,(g)} \longrightarrow NO_{(g)} + H_2O_{(g)}$

**1.** $\mathbf{KClO_{3(s)} \longrightarrow KCl_{(s)} + O_{2(g)}}$

Write down the number of atoms on each side.

| **Reactants** $\longrightarrow$ | **Products** |
|---|---|
| K (1) | K (1) |
| Cl (1) | Cl (1) |
| O (3) | O (2) |

It is clear that 'K' and 'Cl' elements have the same number of atoms on both sides of the equation, but the Oxygen atoms are not balanced. So, we place 2 on left hand side and 3 on right hand side (cross multiply) to balance the Oxygen atoms.

$2KClO_3 \longrightarrow KCl + 3O_2$

| **Reactants** $\longrightarrow$ | **Products** |
|---|---|
| K (2) | K (1) |
| Cl (2) | Cl (1) |
| O (6) | O (6) |

Now we simply balance 'K' by placing '2' in front of 'KCl'.

$2KClO_3 \longrightarrow 2KCl + 3O_2$

| **Reactants** $\longrightarrow$ | **Products** |
|---|---|
| K (2) | K (2) |
| Cl (2) | Cl (2) |
| O (6) | O (6) |

This equation is now balanced.

$\mathbf{2KClO_{3\,(s)} \longrightarrow 2KCl_{(s)} + 3O_{2(g)}}$

**2.** $\mathbf{H_{2(g)} + O_{2(g)} \longrightarrow H_2O_{(l)}}$

Write down the number of atoms on each side.

| **Reactants** $\longrightarrow$ | **Products** |
|---|---|
| H (2) | H (2) |
| O (2) | O (1) |

On both sides the 'H' atoms are same but 'O' atoms are different. So, by placing 2 in front of '$H_2O$', the 'O' atoms will become same.

$\mathbf{H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}}$

| **Reactants** $\longrightarrow$ | **Products** |
|---|---|
| H (2) | H (4) |
| O (2) | O (2) |

Now on both sides, the 'O' atoms are same but 'H' atoms are different. By placing 2 in front of $H_2$ on the reactant side, the 'H' atoms will become same.

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2\,H_2O_{(l)}$$

| Reactants | → | Products |
|---|---|---|
| H (4) | | H (4) |
| O (2) | | O (2) |

This equation is now balanced.

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$$

3. $CH_{4(g)} + O_{2(g)} \longrightarrow$ [illegible] $_{(g)}$

| Reactants | → | Products |
|---|---|---|
| C (1) | | C (1) |
| H (4) | | H (2) |
| O (2) | | O (3) |

On both sides, 'C' atoms are same but 'H' and 'O' atoms are different. So, we place '2' in front of $H_2O$.

$$CH_{4(g)} + O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

| Reactants | → | Products |
|---|---|---|
| C (1) | | C (1) |
| H (4) | | H (4) |
| O (2) | | O (4) |

Now 'C' and 'H' atoms are same on both sides but 'O' atoms are different. We place 2 in front of '$O_2$' on the reactant side.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

| Reactants | → | Products |
|---|---|---|
| C (1) | | C (1) |
| H (4) | | H (4) |
| O (4) | | O (4) |

Now the equation is balanced.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

4. $NH_3 + O_2 \longrightarrow NO + H_2O$

| Reactants | → | Products |
|---|---|---|
| N (1) | | N (1) |
| H (3) | | H (2) |
| O (2) | | O (2) |

On both sides, 'N' and 'O' are balanced, but 'H' is not balanced. Place '4' in front of '$NH_3$' and '4' in front of 'NO' to balance 'N' atoms.

$$4NH_3 + O_2 \longrightarrow 4NO + H_2O$$

| Reactants | → | Products |
|---|---|---|
| N (4) | | N (4) |
| H (12) | | H (2) |
| O (2) | | O (5) |

Now, 'N' atom are balanced but 'H' and 'O' are not balanced. To balance 'H', we place '6' in front of '$H_2O$'.

$$4NH_3 + O_2 \longrightarrow 4NO + 6H_2O$$

| Reactants | → | Products |
|---|---|---|
| N (4) | | N (4) |
| H (12) | | H (12) |
| O (2) | | O (10) |

Now 'N' and 'H' are balanced on both sides but 'O' are not balanced. To balance 'O', place '5' in front of '$O_2$'.

$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$

**Reactants** $\longrightarrow$ **Products**

| Reactants | Products |
|---|---|
| N (4) | N (4) |
| H (12) | H (12) |
| O (10) | O (10) |

Now the equation is balanced.

$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$

## CONCEPT OF MOLE RATIO TO CALCULATE THE AMOUNT OF REACTANTS:

Q. Consider the following reaction.

$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(l)}$

i) How many moles of Oxygen are needed to react with 4.5 moles of Hydrogen?

ii) How many grams of Hydrogen will completely react with 100 g of Oxygen to form water?

ATOMIC MASSES: H = 1. O = 16

**Solution (i)**

| | $2H_2(g)$ + | $O_2(g) \longrightarrow$ | $2H_2O(l)$ |
|---|---|---|---|
| | **2 moles** | **1 mole** | **2 moles** |
| **Given:** | 4.5 moles | —— | —— |
| **Required:** | —— | moles? | —— |

2 moles '$H_2$' react with 1 mole '$O_2$'.

1 mole '$H_2$' reacts with $\frac{1}{2}$ mole of '$O_2$'.

4.5 moles '$H_2$' react with $\frac{1}{2}$ x 4.5 moles of '$O_2$'

**4.5 moles '$H_2$' react with 2.25 moles of '$O_2$'**

**Solution (ii)**

| $2H_{2(g)}$ + | $O_{2(g)} \longrightarrow$ | $2H_2O_{(l)}$ |
|---|---|---|
| **2 moles** | **1 mole** | **2 moles** |
| 2 x 2g | 32g | 2 x 18g |
| 4g | 32g | 36g |

32g of '$O_2$' react with 4g '$H_2$'

1g of '$O_2$' reacts with $\frac{4}{32}$ g '$H_2$'

100g of '$O_2$' react with $\frac{4}{32}$ x 100g $H_2$

= 12.5g

**100g of '$O_2$' react with 12.5g '$H_2$'**

RESULT:

i) Number of moles of Oxygen = 2.25 moles.

ii) 100 g of Oxygen require = 12.5g of $H_2$.

# EXERCISE

**Q.1 Fill in the blanks:**

(i) 18 grams of $H_2O$ contain ____________ molecules.

(ii) A change which alters the composition of a substance is called __________.

(iii) A reaction, in which a chemical substance breaks down to form two or more simpler substances, is called ______________.

(iv) The reaction of NaCl with $AgNO_3$ is given as:
$NaCl_{(aq)}$ + $AgNO_3$ [illegible]
[illegible] of ________________ reaction.

(v) When metals react with acids or water, they produce __________ gas.

(vi) ___________ is the reaction in which two or more substances combine together to form a single substance.

(vii) A reaction in which a substance burns in oxygen to produce heat and flame is called _____________.

(viii) _____________ is the short hand method to describe a chemical reaction.

(ix) The reaction $Zn + 2HCl \longrightarrow ZnCl_2 + H_2 (g)$ is ____________.

**Q.2 Tick the correct answer:**

(i) Mass can neither be created nor destroyed during a chemical change. is the statement of the:
(a) Law of conservation of mass
(b) Law of definite proportions
(c) Law of multiple proportions
(d) Law of reciprocal proportions

(ii) A given compound always contains exactly the same proportions of elements by mass, is the statement of:
(a) Law of conservation of mass
(b) Law of definite proportions
(c) Law of multiple proportions
(d) Law of reciprocal proportions

(iii) The sum of the average mass of natural mixture of isotopes, which is compared to the mass of C-12 is called the:
(a) Atomic number
(b) Mass number
(c) Atomic mass
(d) none of these

(iv) A formula that gives only the relative number of each type of atoms in a molecule is called the:
(a) Empirical formula
(b) Molecular formula
(c) Molecular mass
(d) Formula mass

(v) A formula that indicates the actual number and types of atoms in a molecule is called the:
(a) Empirical formula
(b) Molecular formula
(c) Molecular mass
(d) Formula mass

(vi) The sum of the atomic masses of all atoms in a molecule is called the:
(a) Empirical formula
(b) Molecular formula
(c) Molecular mass
(d) Formula mass

(vii) The sum of the atomic masses of all atoms in a formula unit of substance is called the:
(a) Empirical formula
(b) Molecular formula
(c) Molecular mass
(d) Formula mass

(viii) The mass of '1' mole of any substance expressed in gram is called the:
(a) Empirical formula
(b) Molecular formula
(c) Molecular mass
(d) Molar mass

(ix) 44 a.m.u. of $CO_2$ is equal to the:
(a) Molar mass
(b) Atomic mass
(c) Molecular mass
(d) Mass number

(x) 5 moles of $H_2O$ are equal to:
(a) 80 g  (b) 90 g  (c) 100g  (d) 90 a.m.u.

## ANSWER KEY

Q.1

| | |
|---|---|
| i) $6.02 \times 10^{23}$ | ii) Chemical change |
| iii) Decomposition reaction | iv) Double displacement |
| v) $H_2$ | vi) Addition |
| vii) Combustion reaction | viii) Chemical equation |
| ix) Single displacement reaction | |

Q.2

| | | | | |
|---|---|---|---|---|
| i) a | ii) b | iii) c | iv) b | v) b |
| vi) c | vii) d | viii) d | ix) c | x) b |

**Q.3 Write the answers of the following questions:**

(i) State the law of conservation of mass. Describe Landolt experiment.

**Ans.** on page # 3

(ii) State the law of definite proportions in your own words.

**Ans.** on page # 4

(iii) What is the law of multiple proportions? Explain with examples.

**Ans.** on page # 4

(iv) State the law of reciprocal proportions and illustrate it with examples.

**Ans.** on page # 5

(v) What is empirical formula? Give an example.

**Ans.** on page # 6

(vi) What is molecular formula? Give an example.

**Ans.** on page # 6

(vii) Can one substance have the same empirical formula and molecular formula? Explain with examples.

**Ans.** Most inorganic substances have the same empirical formula and molecular formula.

**Explanation:**

Inorganic compounds show the same empirical formula and molecular formula because formula shows the relative ratio of atoms as well as the real ratio of atoms simultaneously.

**Examples:**

$H_2O$, $CO_2$, $HCl$, $H_2SO_4$, $NaCl$, $Na_2SO_4$, $CuSO_4$ etc. are the formulae of some compounds which are empirical as well as molecular formulae.

(viii) What is the difference between empirical formula and molecular formula?

Ans. on page # 6

(ix) What is atomic mass unit?

Ans. The mass of $\frac{1}{12}$ part of Carbon atom is considered as atomic mass unit.

(x) The value of the atomic mass of Carbon in the periodic table is 12.011 a.m.u. rather than 12.00 a.m.u. Explain.

**Explanation:**

The atomic mass of Carbon in the periodic table is 12.011 a.m.u. rather than 12.00 a.m.u. because, according to definition, when average isotopic mass of carbon is compared to the mass of $\frac{1}{12}$ th of carbon atom, the result obtained is 12.011 a.m.u.

(xi) Calculate the average atomic mass of Chlorine if 75% of $_{17}Cl^{35}$ and 25% $_{17}Cl^{37}$ isotopes are present in Chlorine.

**Solution:**

$$\text{Average atomic mass of Chlorine} = \frac{75}{100} \times 35 + \frac{25}{100} \times 37$$

$$= 0.75 \times 35 + 0.25 \times 37$$

$$= 26.25 + 9.25$$

$$\text{Average atomic mass of Cl} = 35.5 \text{ a.m.u.}$$

$$\boxed{\text{Average atomic mass of Chlorine} = 35.5 \text{ a.m.u.}}$$ Ans.



(xii) How many atoms are there in 5 moles of Sulphur?

**Solution:**

$$1 \text{ mol Sulphur contain} = 6.02 \times 10^{23} \text{ atoms}$$

$$5 \text{ mol Sulphur contain} = 5 \times 6.02 \times 10^{23}$$

$$= 30.1 \times 10^{23} \text{ atoms}$$

$$5 \text{ mol of Sulphur contain} = 30.1 \times 10^{23} \text{ atoms}$$

(xiii) What is a mole? What is the molar mass of a substance? Find the molar mass of $SO_2$.

Ans. on page # 7

(xiv) What is Avogadro's number? Find the number of Oxygen atoms in 4g of Oxygen.

**Ans.** on page # 7, 8 and 9

(xv) What does Avogadro's number represent?

(xvi) What is the mass in gram of a single atom of each of the following elements?

**(a) Carbon (C)** **(b) Magnesium (Mg)** **(c) Calcium (Ca)**

**Ans.** (a) Carbon (C)

**Solution:**

Mass of $6.02\times10^{23}$ atoms of Carbon = 12g

$$\text{Mass of 1 atom of Carbon} = \frac{12}{6.02\times10^{23}}$$

$$= 1.99\times10^{-23}\,g$$

$\boxed{\text{Mass of a single atom of Carbon} = 1.99\times10^{-23}\,g}$ **Ans.**

**(b) Magnesium (Mg)**

**Solution:**

$$\text{Mass} = \frac{\text{Atomic Mass} \times \text{number of atoms}}{N_A}$$

(c) Calcium(Ca) Solve yourself by using the above formula.

(xvii) What is the mass in grams of $1\times10^{20}$ atoms of Na?

**Ans.** Solve by using formula given in Q. (xvi)

(xviii) Define the following:

(a) Molecular formula mass **(b)** Formula mass (c) Molar mass

**Ans.** on page 6, 7

(xix) Calculate the molecular mass (in a.m.u.) of each of the following substances.

(a) $H_2O$ (b) $H_2O_2$ (c) $C_6H_6$ (d) $C_2H_6O$

**Ans.** Solve yourself.

(xx) **Calculate the formula mass ( in a.m.u.) of each of the following:**

(a) $KNO_3$ (b) $Al_2O_3$ (c) $CaCO_3$ (d) $MgCl_2$

**Ans.** Solve yourself.

(xxi) Calculate the molar masses of the following substances:

(a) $S_8$ (b) $CS_2$

(c) $CHCl_3$ (Chloroform) (d) $CH_3-COOH$ (Acetic acid)

**Ans.** Solve yourself.

**(xxii)** The formula for rust is $Fe_2O_3$. How many moles of Fe are present in 30g of rust?

**Solution:**

Molar mass = $Fe_2O_3$

$= Fe_2 = 56 \times 2 = 112$

$= O_3 = 16 \times 3 = \underline{048}$

$= \underline{160}$ g

Formula Mass of rust = 160g

1g rust contains $\frac{2}{160}$ moles of Fe

30g rust contain $\frac{2}{160} \times 30$

$= \frac{60}{160}$

= 0.375 moles of Fe

$\boxed{\text{0.375 moles of Fe are present in 30g of rust.}}$ **Ans.**

**(xxiii)** Define the following terms.

(a) Chemical reaction (a) Reactants (d) Products

**Ans.** on page # 9

**(xxiv)** What is chemical equation? What is a co-efficient? Give an example of balanced equation.

**Ans.** on page # 15, 16

**(xxv)** What is combination reaction? Give an example.

**Ans.** on page # 10

**(xxvi)** What is decomposition reaction? Will two or more elements always be the products of this type of reaction? Explain with examples.

**Ans.** on page # 10

**(xxvii)** What is single replacement reaction? Give an example.

**Ans.** on page # 10

**(xxviii)** Explain double displacement reaction with examples.

**Ans.** on page # 11

**(xxix)** Balance the following equations by inspection method?

(a) $C + O_2 \longrightarrow CO$

(b) $CO + O_2 \longrightarrow CO_2$

(c) $KNO_3 \longrightarrow KNO_2 + O_2$

(d) $NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$

(e) $CaCO_3 + HCl \quad CaCl_2 + H_2O + CO_2$

(f) $NH_3 + O_2 \quad NO + H_2O$

**Ans.** Do yourself.

(xxx) Which of the following reaction is either a decomposition reaction or combination reaction?

(a) $MgCO_3 \longrightarrow MgO + CO_2$

(c) $BaCO_3 \longrightarrow BaO + CO_2$

(d) $N_2 + 3H_2 \longrightarrow 2NH_3$

**Ans.** Do yourself.

(xxxi) Balance the equation and decide which one is single replacement reaction.

(a) $C_2H_4 + H_2 \longrightarrow C_4H_8$

(b) $Ca + H_2O \longrightarrow Ca(OH)_2 + H_2$

(c) $C_2H_5OH + Na \longrightarrow C_2H_5ONa + H_2$

**Ans.** Do yourself.

(xxxii) Balance the following equations. State which of these is a decomposition reaction or combination reaction.

(a) $CH_4 + O_2 \longrightarrow CO_2 + H_2O$

(b) $NO_2 \longrightarrow NO + O_2$

(c) $Na + O_2 \longrightarrow Na_2O$

**Ans.** Do yourself.

(xxxiii) Consider the combination of (CO) with oxygen ($O_2$) gas.

$$2CO + O_2 \longrightarrow 2CO_2$$

Calculate the number of moles of ($CO_2$) produced when 50 moles of oxygen are reacted with all of CO.

**Ans. Solution:**

| | $2CO$ | $+\ O_2$ | $\longrightarrow$ | $2CO_2$ |
|---|---|---|---|---|
| | 2 moles | 1 mole | | 2 moles |
| **Given:** | —— | 50 mole | | —— |
| **Required:** | —— | —— | | Moles? |

1 mole of '$O_2$' produces 2 moles of '$CO_2$'

50 moles of '$O_2$' produce 2 x 50 = 100 moles '$CO_2$'

**50 moles of '$O_2$' produce 100 moles '$CO_2$'**

(xxxiv) Calcium carbonate ($CaCO_3$) on heating gives calcium oxide (CaO) and $CO_2$ gas.

$$CaCO_3 \longrightarrow CaO + CO_2$$

Calculate how many grams of calcium oxide (CaO) can be obtained by heating 8 moles of $CaCO_3$.

**Ans.** **Atomic Masses:** Ca = 40, C = 12, O = 16

**Solution:** $CaCO_3 \longrightarrow CaO + CO_2$

1 mole — 1 mole — 1 mole

**Given:** 8 moles — —— ——

**Required:** —— Mass ?

1 mole of '$CaCO_3$' produces 1 mole of '$CaO$'

8 moles of '$CaCO_3$' produce 8 moles of '$CaO$'

= 8 x [40 + 16 ] g

= 8 x [56] g

= 8 x 88 g

= 448 g

**8 moles of '$CaCO_3$' produce 448 g of '$CaO$'**

Q.(xxxv) Silicon tetrachloride ($SiCl_4$) can be prepared by heating (Si) in Chlorine gas ($Cl_2$).

$$Si + 2Cl_2 \longrightarrow SiCl_4$$

If we want to prepare 10 moles of ($SiCl_4$), how many moles of molecular Chlorine ($Cl_2$) will be used in the reaction?

**Solution:**

$$Si + 2Cl_2 \longrightarrow SiCl_4$$

1 mole — 2 moles — 1 mole

1 mole of '$SiCl_4$' requires 2 moles of '$Cl_2$'

10 moles of '$SiCl_4$' require 2 x 10 moles of '$Cl_2$'

**10 moles of '$SiCl_4$' require 20 moles of '$Cl_2$'**

Q.(xxxvi) Fermentation is chemical decomposition, in which Glucose ($C_6H_{12}O_6$) is converted into Ethyl alcohol ($C_2H_5$-OH) and Carbon dioxide ($CO_2$).

$$C_6H_{12}O_6 \xrightarrow{\text{Fermentation}} 2C_2H_5\text{-}OH + 2CO_2$$

What will be the amount of Ethyl alcohol in grams and moles, which can be obtained by fermentation of 5000g of Glucose?

**Atomic Masses:** **C = 12, H = 12, O = 16**

**Solution (i)** $C_6H_{12}O_6 \xrightarrow{\text{Fermentation}} 2C_2H_5\text{-}OH + 2CO_2$

1 mole — 2 moles — 2 moles

**Given:** 5000 g — —— ——

**Required:** —— Amount in gram? Mole ?

Calculation of Molar mass;

Molar mass of '$C_6H_{12}O_6$' = $6 \times 12 + 12 \times 1 + 6 \times 16$

= $72 + 12 + 96$

Molar mass of '$C_2H_5$-OH' = $2 \times 12 + 5 \times 1 + 1 \times 16 + 1 \times 1$

= $24 + 5 + 16 + 1$

= 46 a.m.u.

$$\text{Mole} = \frac{\text{Mass of substance (g)}}{\text{Molar mass}}$$

$$\text{Moles of Glucose} = \frac{5000g}{180g}$$

Moles of Glucose = 27.77 mol

$$(C_6H_{12}O_6) \xrightarrow{\text{Fermentation}} 2C_2H_5\text{-}OH + 2CO_2$$

1 mole 2 moles 2 moles

1 mol of Glucose produces 2 moles of Ethyl alcohol.

27.77 mol of Glucose produce 2 x 27.77 mol of Ethyl alcohol.

= 55.55 mol of Ethyl alcohol.

∴ **5000g of Glucose produce 55.55 mol of Ethyl alcohol**

**Solution (ii)** Mass = Mole x Molar mass

Mass of Ethyl alcohol = Moles of Ethyl alcohol x molar mass of Ethyl alcohol

= 55.55 x 46 g

Mass of Ethyl alcohol = 2555.3 g

**5000 g of Glucose produce = 2555.3 g of Ethyl alcohol**

**Answers:**

1. Mol of Ethyl alcohol produced = 55.55 mol.
2. Mass of Ethyl alcohol = 2555.3 g.

SESSION 2016-2017

# CLASS-IX

# CHEMISTRY

## Chapter # 3

## ATOMIC STRUCTURE

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# ATOMIC STRUCTURE 3

## ELEMENT:

The simplest form of any substance which contains the same type of atoms is called element. An element contains atoms of the same atomic number.

## ATOM:

*"A tiny particle of an element is called atom."*

The Greek Philosopher **Democritus** gave the idea that all elements consist of very small indivisible particles called atoms. The word **atom** is taken from the Greek word "**Atomos**" which means 'one that cannot be cut'. In other words, atom is **indivisible** (cannot be divided).

Scientifically, ***"Atom of an element consists of sub-atomic particles called electrons, protons and neutrons.***

## Dalton's Atomic Theory:

This theory was given by a British school teacher, **John Dalton** in **1808**. He stated:

1. Elements are made up of small indivisible, indestructible particles called atoms.
2. Atoms of an element have same size, shape, chemical properties and mass.
3. Atoms of one element are different from atoms of other elements.
4. Compounds are formed when atoms of more than one type of elements combine in a ratio of simple whole number.
5. A chemical reaction is a rearrangement of atoms, but atoms are not changed themselves, it means that atoms are neither created nor destroyed in chemical reactions.

## Defects in Dalton's Atomic Theory:

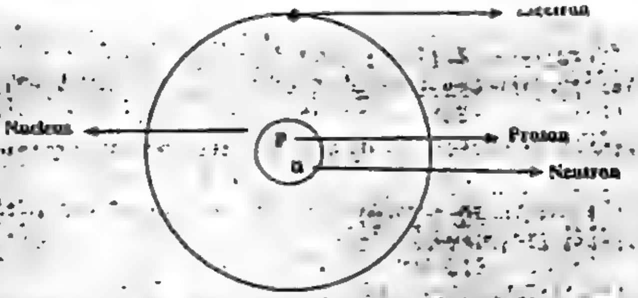
1. Atoms of elements are **indivisible** but modern theory confirmed that each atom consists of very small particles in the form of Electrons, Protons and Neutrons.
2. Atoms of an element are **identical** in all aspects but modern theory confirmed that isotopes of an element have different masses.
   e.g. $Cl^{35}$ and $Cl^{37}$ are two isotopes of Chlorine. This difference is due to difference of Neutrons.

## Modern Atomic Theory:

1. Element is composed of tiny particles called atom. (Atom possesses all the properties of an element).
2. Atom of an element consists of sub-atomic particles called electrons, protons and neutrons.
3. Atoms of an element are identical in size, shape and chemical properties but they have different masses. (Such atoms of an element are called Isotopes).
4. Compounds are formed when atoms of more than one type of elements combine in a ratio of simple whole number.
5. A chemical reaction is a rearrangement of atoms, but atoms are not changed themselves, it means that atoms are neither created nor destroyed in chemical reactions.

## FUNDAMENTAL PARTICLES OF AN ATOM:

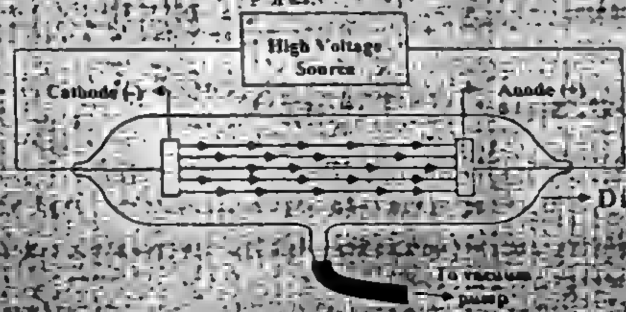
Each atom consists of three subatomic particles called Electron, Proton and Neutron. These subatomic particles are also called ***Fundamental Particles.***




## DISCOVERY OF ELECTRONS
## OR
## CATHODE (DISCHARGE) TUBE EXPERIMENT

### Introduction:

Electron is a fundamental particle of each atom having negative charge. This negatively charged particle was discovered by **J.J. Thomson** in **1897**.




### Construction:

This experiment consists of a glass tube of thick walls. The tube is fitted with two [illegible] electrodes connected with negative and positive terminals of a high voltage [illegible]. These plates are called Cathode and Anode respectively. This [illegible] tube [illegible] of a small outlet tube connected with vacuum pump.

### Working:

[illegible] is filled with a gas at ordinary pressure. A vacuum pump evacuates the [illegible] from the tube so that the pressure is reduced inside the tube. A high voltage is [illegible] through the electrodes (Cathode and Anode). [illegible] high voltage [illegible] electrical discharge in the tube is observed [illegible] the electrodes.

### Observation:

Streaks (lines) of bluish light moving from Cathode to Anode are observed. It appears that these rays travel in straight lines from Cathode to Anode and a glow is observed on the tube toward Anode side where these rays strike.

## Conclusions:

These particles were passed through electric and magnetic field in the form of rays. It was observed that the particles were deviated from their path towards the positive plate of the magnetic field, so it is a clear indication that these particles are negatively charged. They are called **electrons.**

**The same experiment was performed by changing the gas in the tube. It ... that the nature of these particles remained the same.**

**The same experiment was performed by changing the metal of the electrodes. It was observed that the nature of the particles remained the same.**

## PROPERTIES OF CATHODE RAYS (ELECTRONS):

i) If an opaque object is placed in the path of Cathode rays, a shadow is observed which indicates that these particles travel in straight lines.

ii) If a light paddle wheel is placed in the path of Cathode rays, the wheel rotates which indicates that Cathode rays are material particles. The mass of each particle was found to be 1837 times less than the mass of a proton.

iii) When these rays strike with glass or some other material then fluorescence (glow) is produced.

iv) When Cathode rays pass through electric and magnetic fields then they deflect towards the positive plate which indicates that these are negatively charged particles.

v) These particles are material in nature and can produce mechanical pressure and are moving with certain velocity, so they posses Kinetic energy.

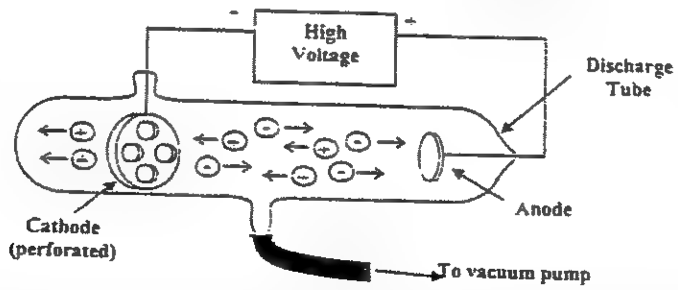
vi) The $\frac{e}{m}$ ratio that is $\left(\frac{\text{charge}}{\text{mass}}\right)$ ratio of Cathode particles is $1.7588\times10^{8}\ \frac{C}{g}$ $\left(\frac{\text{Coulomb}}{\text{gram}}\right)$. The $\frac{e}{m}$ ratio of electron is the also the same. The Cathode particle of any other gas also carries the same $\frac{e}{m}$ ratio.

## DISCOVERY OF PROTONS (GOLDSTEIN EXPERIMENT):

In 1886, **Goldstein**, a German physicist, performed an experiment to show the presence of material particles which are positive in nature.

## EXPERIMENT:

The discharge tube is filled with hydrogen gas while the cathode is perforated. When high voltage is provided to the gas at very low pressure, light is observed behind the cathode.



## Conclusion:

Light behind the cathode is observed due to the ionization of gas filled in the tube.

e.g. $H \longrightarrow \underset{\text{Proton}}{H^+} + \underset{\text{Electron}}{e^-}$

### Properties of Positive rays:

i) These rays travel in straight line in the direction from Anode to Cathode.

ii) When these rays are passed through electric field, then these particles were deflected towards the negative plate, which indicates that they are positively charged particles.

iii) The $\frac{e}{m}$ ratio of positive particle is much smaller than that of electrons.

## Discovery of Neutrons:

In **1932**, the British Physicist, **James Chadwick** discovered a third fundamental particle of atom with the help of artificial radioactivity. This particle is neutral in nature, having mass nearly equal to the mass of a proton.

### Properties of Electron, Proton and Neutron:

| ELECTRON | PROTON | NEUTRON |
|---|---|---|
| ***1) Charge*** | ***1) Charge*** | ***1) Charge*** |
| The charge of Electron is negative. | The charge of Proton is positive. | Neutron is neutral. |
| ***2) Quantity of charge*** | ***2) Quantity of charge*** | ***2) Quantity of charge*** |
| $1.602 \times 10^{-19}$ Coulomb or $4.8 \times 10^{-10}$ e.s.u. | $1.602 \times 10^{-19}$ Coulomb or $4.8 \times 10^{-10}$ e.s.u | No charge. |
| ***3) Mass*** | ***3) Mass*** | ***3) Mass*** |
| Mass of electron is $9.11 \times 10^{-31}$ kg. or $9.11 \times 10^{-28}$ g. | Mass of Proton is $1.673 \times 10^{-27}$ kg. or $1.673 \times 10^{-24}$ g. | Mass of Neutron is $1.675 \times 10^{-27}$ kg. or $1.675 \times 10^{-24}$ g. |
| ***4) Charge unit -1*** | ***4) Charge unit +1*** | ***4) Charge unit (Zero)*** |

## RADIOACTIVITY

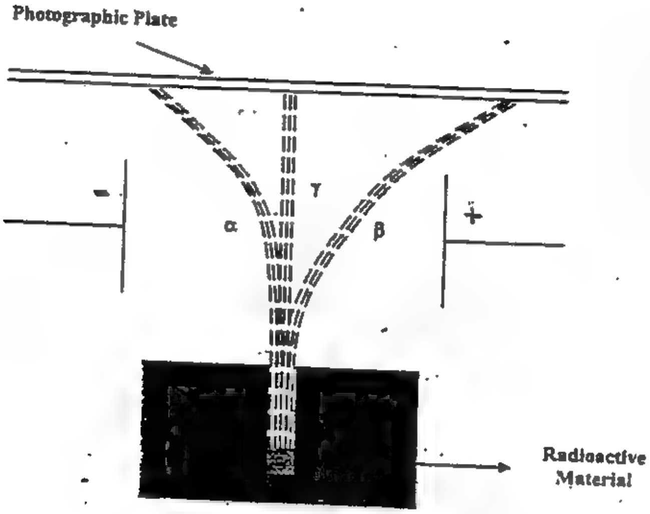
*Radioactivity is a phenomenon related to the spontaneous disintegration of nucleus of an atom and emission of invisible radiations from the nucleus of an atom.*

## Radioactive Substance:

**The substance which emits radiations is called radioactive substance.**

Uranium (U), Thorium (Th) and Polonium (Po) are common examples of radioactive elements.

## Type of Rays ($\alpha$ , $\beta$ and $\gamma$ Rays):




In 1902, a British Physicist, **Ernest Rutherford** performed an experiment to study the nature of radioactive rays.

A radioactive material was placed in the cavity of a thick Lead (Pb) block. Radiations coming out of the cavity were passed through strong electric field.

It was observed that these radiations split into three directions.

**Positive charged particles or Alpha ($\alpha$) rays:**

i) Positive charged particles were deflected towards the negative plate.

ii) These positive charged particles are called Alpha ($\alpha$) particles.

**Negatively charged particles or Beta ($\beta$) rays:**

i) Negative charged particles were deflected towards the positive plate.

ii) These negative charged particles are called Beta ($\beta$) particles.

**Neutral rays or Gamma ($\gamma$) rays**

i) These rays remain un-deflected (not bent in any direction), showing that these are neutral (having no charge).

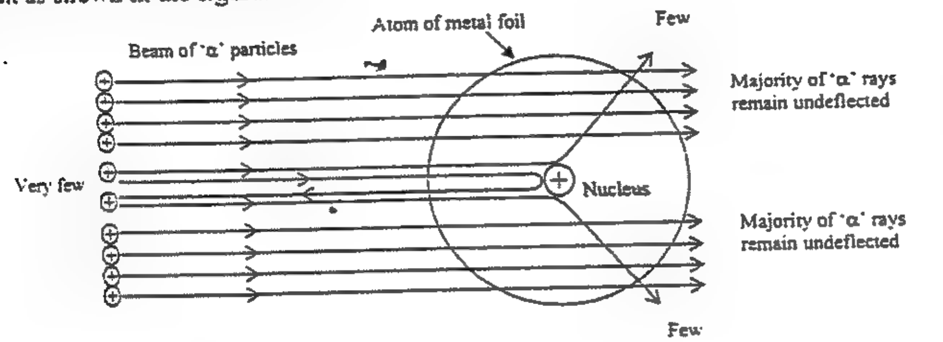
ii) These rays are called Gamma ($\gamma$) rays. They are not matter (particle) in nature.

## Rutherford Atomic Model:

In 1911, **Lord Rutherford** successfully performed an experiment to study the structure of an atom.

### Experiment:

Rutherford bombarded Alpha (α) particles on a very thin Gold metal foil. He found that most of the Alpha particles passed through it without any deflection. Some of the Alpha particles were deflected at large angles. Very few Alpha particles bounced back as shown in the figure:




### Observations and Conclusions:

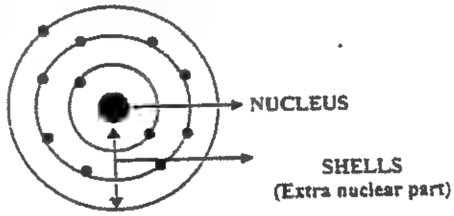
(1) Most of the ' α ' particles passed undeflected, so most of the portion of the atom is empty.

(2) Few 'α' particles deflected with large angle, so the middle portion of the atom has entire positive charge in that portion called ***nucleus.*** Nucleus of the atom is positively charged.

(3) Very few 'α' particles bounced back, so the nucleus is the hardest portion of the atom and nearly the entire mass is concentrated in the nucleus.

(4) Since atom as a whole is neutral (having no charge), so there must be negative charge outside the nucleus.

(5) Electrons revolve round the nucleus in various orbits called Shells or Energy levels.




### Weaknesses or Defects in Rutherford's Atomic Model:

i) According to Classical Electromagnetic Theory, a charged particle releases energy during its movement. Since the electron revolves continuously, so it evolves (releases) energy and due to loss of energy, the electron must fall into the nucleus. This is not true.

ii) Since the electron revolves continuously, the energy dissipated must be continuous, so a continuous spectrum must be formed. But in actual practice, line spectrum is obtained.

## Bohr's Atomic Model:

In 1913, a Danish Physicist, **Neil Bohr** gave a theory to resolve the defects of Rutherford's atomic model. Bohr's atomic model is based on the following points:

i) Electron is negatively charged particle but, during its revolution, it does not release energy. So, it will not fall into the nucleus.

ii) When electron gains energy, it moves [illegible] there and finally returns back to its original energy level.

iii) When electron releases energy, it moves back to lower energy level. During the release (dissipation) of energy (quantum), some lines (colour) are observed on the screen. This is called line spectrum.

iv) The quantum energy is directly proportional to the frequency of the radiation.

i.e. $\Delta E = E_2 - E_1 = h\nu$

Where h = Planck's constant. $\nu$ = Frequency of the radiation.

## Atomic Number (Z):

*"The number of protons present in the nucleus of an atom is called atomic number."*

Atomic number is generally denoted by (Z). Atom is neutral because the number of protons is equal to the number of electrons. All elements are identified by their atomic numbers. No two elements can have the same atomic number.

### Consider the example of Carbon and Nitrogen:

Atomic number of Carbon is 6, but Atomic number of Nitrogen is 7, so the properties of Carbon and Nitrogen are different. Because the number of protons of Carbon is 6, the number of electrons of Carbon is also 6. On the other hand, number of protons of Nitrogen is 7, so the number of electrons of Nitrogen is 7.

## Mass Number (A):

*"The sum of protons and neutrons in the nucleus of an atom is called mass number."*

Mass number (A) = Number of protons (Z) + Number of neutrons (n).

$$A = Z + n$$

Number of neutrons = A – Z

### Consider the example of Sodium (Na):

| | | | | |
|---|---|---|---|---|
| Atomic number of Na | = | 11 and the mass number of Na = 23. | | |
| Number of protons | = | 11 | = | number of electrons |
| Number of neutrons | = | A – Z | | |
| | = | 23 - 11 | | |
| Number of neutrons (n) | = | 12 | | |

Usually, the mass number and atomic number are written as:

Mass number / Atomic number $^{23}_{11}Na$

## ISOTOPES

***Atoms of an element having the same number of protons but different number of neutrons are called Isotopes.***

*OR*

***Isotopes are the atoms of the same element having the same atomic number but different atomic masses.***

Chemical properties of an element depend upon the number of electrons in elements. Therefore all isotopes of an element ***have the same chemical properties*** but their ***physical properties are different*** due to different mass numbers.

*Consider two isotopes of Chlorine (i) Cl-35 and (ii) Cl-37.*

For Cl-35, the atomic number is 17, so this Chlorine contains 17 protons, 17 electrons and 18 neutrons. (The number of neutrons = 35 - 17 = 18).

For Cl-37, the atomic number is 17, so this Chlorine contains 17 protons, 17 electrons and 20 neutrons. (The number of neutrons = 37 - 17 = 20).

## EXAMPLES OF ISOTOPES

### Isotopes of Hydrogen:

There are three isotopes of Hydrogen:

(i) ${}^{1}_{1}H$ (ii) ${}^{2}_{1}H({}^{2}_{1}D)$ (iii) ${}^{3}_{1}H({}^{3}_{1}T)$

Protium Deuterium Tritium

- Protium contains 1 electron, 1 proton and 1–1 = 0 means no neutron.
- Deuterium contains 1 electron, 1 proton and 2–1 = 1 neutron.
- Tritium contains 1 electron, 1 proton and 3–1 = 2 neutrons.

All these three isotopes of hydrogen have the same chemical properties due to the same number of electrons, but physical properties are different due to different mass numbers or different number of neutrons.

### Isotopes of Oxygen (O):

There are three isotopes of Oxygen O-16, O-17, and O-18.

(i) ${}^{16}_{8}O$ (ii) ${}^{17}_{8}O$ (iii) ${}^{18}_{8}O$

- ${}^{16}_{8}O$ contains 8 electrons, 8 protons and 16-8 = 8 neutrons.
- ${}^{17}_{8}O$ contains 8 electrons, 8 protons and 17-8 = 9 neutrons.
- ${}^{18}_{8}O$ contains 8 electrons, 8 protons and 18-8 = 10 neutrons.

### Isotopes of Uranium (U):

There are three isotopes of Uranium U-234, U-235, and U-236.

(i) ${}^{234}_{92}U$ (ii) ${}^{235}_{92}U$ (iii) ${}^{236}_{92}U$

- ${}^{234}_{92}U$ contains 92 electrons, 92 protons and 234-92 = 142 neutrons.
- ${}^{235}_{92}U$ contains 92 electrons, 92 protons and 235-92 = 143 neutrons.
- ${}^{236}_{92}U$ contains 92 electrons, 92 protons and 236-92 = 144 neutrons.

## Isotopes of Carbon (C):

There are three isotopes of Carbon C-12, C-13, and C-14.

(i) $^{12}_{6}C$ (ii) $^{13}_{6}C$ (iii) $^{14}_{6}C$

- $^{12}_{6}C$ contains 6 electrons, 6 protons and 12-6 = 6 neutrons.
- $^{13}_{6}C$ contains 6 electrons, 6 protons and 13 - 6 ...
- $^{14}_{6}C$ contains 6 electrons, 6 protons and 14-6 = 8 neutrons.

## Applications (Uses) of Isotopes:

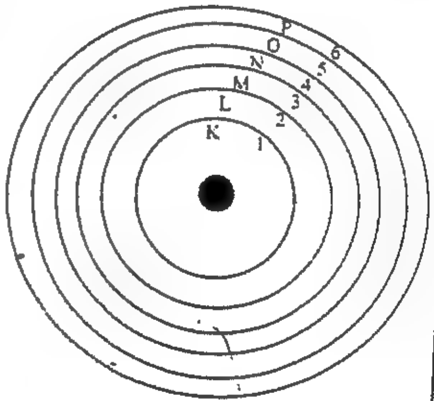
- Usually, isotopes are radioactive in nature except stable isotopes. So, the radioactive isotopes are used as tracers (to trace many hidden things). Therefore, a radioisotope helps in diagnosis of many diseases.
- From a radioactive isotope radiations are emitted, which help in the cure of many diseases like cancer, in which these radiations are used for radiotherapy purpose.

## ELECTRONIC CONFIGURATIONS

Electrons in an atom revolve round its nucleus. These electrons revolve in different circular orbits called **energy levels or shells.**

The distribution of electrons in different energy levels is called **electronic configuration.**

These shells are shown in the diagram.




These shells are designated as K, L, M, N, O and P orbits.

Each shell is also given a number 'n' as 1, 2, 3, 4, 5 and 6 respectively.

On the basis of these numbers, we can calculate the number of maximum electrons in these shells, with the help of the formula $2n^2$.

First 'K' shell contains $2n^2 = 2 \times 1^2 = 2 \times 1 = 2$ electrons (maximum).

Second 'L' shell contains $2n^2 = 2 \times 2^2 = 2 \times 4 = 8$ electrons (maximum).

Third 'M' shell contians $2n^2 = 2 \times 3^2 = 2 \times 9 = 18$ electrons (maximum).

Similarly fourth, fifth and sixth shell contains a maximum of 32, 50 and 72 electrons respectively.

## ARRANGEMENT OF ELECTRONS IN THE FIRST 20 ELEMENTS

| Elements | Atomic Number | Electrons in the Shells | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1st | | 2nd | | 3rd | | 4th | |
| H | 1 | 1 | $1s^1$ | — | | — | | — | |
| He | 2 | 2 | $1s^2$ | | | | | | |
| Li | 3 | 2 | $1s^2$ | 1 | $2s^1$ | — | | — | |
| Be | 4 | 2 | $1s^2$ | 2 | $2s^2$ | | | | |
| B | 5 | 2 | $1s^2$ | 3 | $2s^2 2p^1$ | — | | — | |
| C | 6 | 2 | $1s^2$ | 4 | $2s^2 2p^2$ | — | | — | |
| N | 7 | 2 | $1s^2$ | 5 | $2s^2 2p^3$ | — | | — | |
| O | 8 | 2 | $1s^2$ | 6 | $2s^2 2p^4$ | — | | — | |
| F | 9 | 2 | $1s^2$ | 7 | $2s^2 2p^5$ | — | | — | |
| Ne | 10 | 2 | $1s^2$ | 8 | $2s^2 2p^6$ | — | | — | |
| Na | 11 | 2 | $1s^2$ | 8 | $2s^2 2p^6$ | 1 | $3s^1$ | — | |
| Mg | 12 | 2 | $1s^2$ | 8 | $2s^2 2p^6$ | 2 | $3s^2$ | — | |
| Al | 13 | 2 | $1s^2$ | 8 | $2s^2 2p^6$ | 3 | $3s^2 3p^1$ | — | |
| Si | 14 | 2 | $1s^2$ | 8 | $2s^2 2p^6$ | 4 | $3s^2 3p^2$ | — | |
| P | 15 | 2 | $1s^2$ | 8 | $2s^2 2p^6$ | 5 | $3s^2 3p^3$ | — | |
| S | 16 | 2 | $1s^2$ | 8 | $2s^2 2p^6$ | 6 | $3s^2 3p^4$ | — | |
| Cl | 17 | 2 | $1s^2$ | 8 | $2s^2 2p^6$ | 7 | $3s^2 3p^5$ | — | |
| Ar | 18 | 2 | $1S^2$ | 8 | $2s^2 2p^6$ | 8 | $3s^2 3p^6$ | — | |
| K | 19 | 2 | $1s^2$ | 8 | $2s^2 2p^6$ | 8 | $3s^2 p^6$ | 1 | $4s^1$ |
| Ca | 20 | 2 | $1s^2$ | 8 | $2s^2 2p^6$ | 8 | $3s^2 3p^6$ | 2 | $4s^2$ |

*s, p, d* and *f* are subshells, "s" has maximum capacity of two electrons, "p" has maximum capacity of six electrons, "d" has maximum capacity of ten electrons and "f" has maximum capacity of fourteen electrons.

# EXERCISE

**1. Fill in the blanks:**

i. __________ model says that atom consists of small, dense, positively charged nucleus which is surrounded by electrons revolving around it.

ii. The Atomic number of Sodium is ____________.

iii. ... number of protons + number of neutrons is the __________ of an element.

iv. ___________ are the atoms of the same elements, having the same number of protons but different number of neutrons.

v. The number of isotopes of Hydrogen is ______________.

vi. ____________ is the number of positive charges in the nucleus of an atom.

vii. A-Z indicates the number of __________ in the nucleus of an atom.

viii. Z = number of protons in the nucleus of an atom = number of __________ in a neutral atom.

**2. Tick the correct answer:**

i. **The nucleus of an atom consists of:**

(a) Electrons and protons. (b) Protons and neutrons.
(c) Electrons and neutrons. (d) none of these.

ii. **This particle is the lightest among the following:**

(a) Electron. (b) Proton.
(c) Neutron. (d) α-particle.

iii. **This particle is heavier than others:**

(a) Electron. (b) Proton.
(c) Neutron. (d) α-particle.

iv. **The mass of electron is:**

(a) $9.11 \times 10^{-26}$g. (b) $9.11 \times 10^{-27}$g.
(c) $9.11 \times 10^{-28}$g. (d) $9.11 \times 10^{-30}$g.

v. **The mass of proton is:**

(a) $1.673 \times 10^{-22}$g. (b) $1.673 \times 10^{-23}$g.
(c) $1.673 \times 10^{-24}$g. (d) $1.673 \times 10^{-25}$g.

vi. **Charge on an electron is:**

(a) $1.6 \times 10^{-16}$C. (b) $1.602 \times 10^{-17}$C.
(c) $1.67 \times 10^{-16}$C. (d) $1.602 \times 10^{-19}$C.



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**Answers Q.1**

(i) Rutherford's Atomic (ii) 11 (iii) mass number (iv) Isotopes
(v) three (vi) Atomic Number (vii) Neutrons (viii) Electron

**Answers Q.2**

(i) b (ii) a (iii) d (iv) c (v) c (vi) d

**(i) What evidence is there that electrons are negatively charged particles?**

**Ans.** In Cathode discharge tube experiment, the electrons obtained from gaseous atoms move towards the positive electrode (Anode) and show deflection towards the positive pole in a magnetic field. Hence, electrons are negatively charged particles.

**(ii) What is the proof that all atoms contain electrons?**

**Ans.** Cathode rays were proved as electrons in a discharge tube experiment and this experiment was done repeatedly by changing various gases and by changing various electrodes, but the observations remained the same. As Cathode rays are obtained due to discharging of gases, it is proved that all the atoms contain electrons.

**(iii) Why is it believed that the atom has mostly empty spaces?**

**Ans.** In Rutherford's experiment, most of the alpha particles passed through the atoms undeflected and very few were deflected which proved that the major part of the atom is empty.

**(iv) In what way do isotopes of a given element differ from each other?**

**Ans.** Isotopes of a given element differ from each other due to difference in the number of neutrons or mass numbers (Atomic masses).

**(v) An isotope of Nitrogen (N) contains 7 electrons, 7 protons and 8 neutrons.**

(a) What is its mass number? (b) What its atomic number?

**Ans.** (a) 15 (b) 7

**(vi) C-14 and N-14 both have the same mass number, yet they are different elements. Explain.**

**Ans.** Every element is different due to its specific atomic number. The atomic number of C-14 is 6 so it has 6 protons. The atomic number of N-14 is 7 so it has 7 protons.

**(vii) What are the names of three sub-atomic particles? What are their masses in atomic mass units (a.m.u.) and what is the unit charge on each?**

**Answer on page # 06**

**(viii) Give the names and symbols for the following elements.**

(a) An element with atomic number 6. **Name = Carbon, symbol = C**
(b) An element with 18 protons in the nucleus. **Name = Argon, Symbol = Ar**
(c) An element with 17 electrons. **Name = Chlorine, Symbol = Cl**

**(ix) How many electrons and protons are there in each atom of the following?**

| | Name | Electrons | Protons |
|---|---|---|---|
| (a) | Carbon | 6 | 6 |
| (b) | Aluminium | 13 | 13 |
| (c) | Argon | 18 | 18 |
| (d) | Fluorine | 9 | 9 |
| (e) | Potassium | 19 | 19 |
| (f) | Sulphur | 16 | 16 |

**(x) How many protons, neutrons and electrons are present in the following atoms?**

(a) $^{15}_{7}N$ (b) $^{60}_{27}Co$ (c) $^{131}_{53}I$ (d) $^{207}_{82}Pb$

| | Elements | Electrons | Protons | Neutrons |
|---|---|---|---|---|
| (a) | $^{15}_{7}N$ | 7 | 7 | 8 |
| (b) | $^{60}_{27}Co$ | 27 | 27 | 33 |
| (c) | $^{131}_{53}I$ | 53 | 53 | 78 |
| (d) | $^{207}_{82}Pb$ | 82 | 82 | 125 |

SESSION 2016-2017

# CLASS-IX

# CHEMISTRY

## Chapter # 4

## PERIODICITY OF ELEMENTS

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# PERIODICITY OF ELEMENTS

4

110 elements have been discovered till now. Out of these, 92 elements are naturally occurring elements and the remaining 18 elements have been artificially prepared in the laboratories by nuclear reactions

## HISTORICAL DEVELOPMENT OF THE PERIODIC TABLE:

The Periodic table was arranged by different scientists in a period of time. Following are the details of several stages of the development of periodic table:

### 1. AL-RAZI'S CLASSIFICATION:

Al-Razi classified the elements into metals, non-metals and their derivatives based upon the difference in their physical and chemical properties.

### 2. DOBEREINER'S CLASSIFICATION (Law of Triads):

In 1829, a German chemist, ***Johan Wolfgang Dobereiner*** described a relationship between atomic masses and properties of elements. He arranged similar elements in ***groups of three***. This family of three elements is known as *Dobereiner's triad.*

**Statement:**

*"The atomic mass of the central element is almost equal to the arithmetic mean (average) of the atomic masses of the other two elements in the same triad."*

**Example # 1:**

The relative atomic masses of Chlorine (Cl) and Iodine (I) are 35.5 and 127 respectively. The average mass is 81.2 which is very close to the atomic mass of the middle element Bromine (Br) i.e. 80.

$$\frac{35.5+127}{2}=\frac{162.5}{2}=81.2$$

**Example # 2:**

The relative atomic masses of Lithium (Li) and Potassium (K) are 7 and 39 respectively. The average mass is 23 which is equal to the atomic mass of the middle element Sodium (Na) i.e. 23.

$$\frac{7+39}{2}=\frac{46}{2}=23$$

| TRIAD | TRIAD |
|---|---|
| $^{35.5}Cl$ | $^{7}Li$ |
| $^{80}Br$ | $^{23}Na$ |
| $^{127}I$ | $^{39}K$ |

**Discrepancies:**

This law or rule cannot be extended to the classification of all the elements, because it is true only in the cases of very few elements.

## 3. NEWLANDS' CLASSIFICATION (Law of Octaves):

In 1864, an English chemist, ***John Newlands*** stated his law of octaves. He arranged the elements in order of increasing atomic masses.

**Statement:**

***"If the elements are arranged in ascending order of their atomic masses, then every eighth element shows similar properties to those of the first."***

| Element | *Li* | *Be* | *B* | *C* | *N* | *O* | *F* |
|---|---|---|---|---|---|---|---|
| Atomic Mass | 7 | 9 | 11 | 12 | 14 | 16 | 19 |
| Element | *Na* | *Mg* | *Al* | *Si* | *P* | *S* | *Cl* |
| Atomic Mass | 23 | 24 | 27 | 28 | 31 | 32 | 35.5 |
| Element | *K* | *Ca* | | | | | |
| Atomic Mass | 39 | 40 | | | | | |

From the above chart, it is very clear that the properties of Li, Na and K are similar because these elements fall in the eighth position of the series. Similarly Be, Mg and Ca are similar in properties.

**Discrepancies:**

i. 'H' was not included in this sequence.

ii. This law was not applicable to a large number of elements.

## 4. LOTHAR MEYER'S CLASSIFICATION (Atomic Curve):

In 1869, a German scientist, ***Lothar Meyer*** arranged 56 discovered elements in his periodic table. He described a relationship between atomic masses and atomic volumes.

**Statement:**

***"The arrangement of elements is the periodicity of their atomic volume and atomic masses."***



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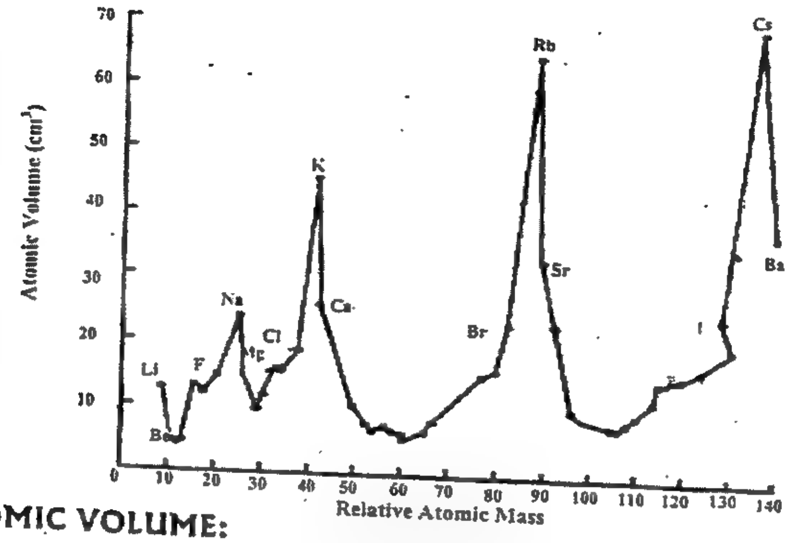
He plotted a graph between atomic volumes of elements against atomic masses. The curve obtained consists of sharp peaks and broad minima.

He observed that the elements with similar properties occupied similar positions on the curve. For example, the highly reactive alkali metals (Li, Na, K, Rb and Cs) occupy the peaks showing that these elements have largest atomic volumes.




## ATOMIC VOLUME:

*"The space occupied by 1 gram mole (1 mole) of an element in solid state.*

## PERIODICITY:

*"Repetition of similar properties after a regular interval (gap) is called Periodicity."*

## 5. MENDELEEV'S CLASSIFICATION (Periodic Law):

In 1869, a Russian chemist, ***Dimitri Mendeleev*** gave a new idea for the arrangement of elements.

## Statement:

*"The properties of elements are the periodic function of their Atomic Weights."*

Periodic function means that every ***ninth*** element is similar to its first element Mendeleev arranged the elements in *12 horizontal rows* called **periods** and *8 vertical columns* called **groups**. The eight groups were further divided into sub-groups.

## Salient Features (Advantages) of Mendeleev's Periodic Table:

(i) He arranged elements in eight vertical columns (groups) and twelve horizontal rows (periods).

(ii) Elements in a group show similar chemical properties, while elements in a period may show periodic trend in physical properties.

(iii) He corrected the atomic masses of many discovered elements.

(iv) He left many vacant spaces for undiscovered elements. He predicted the physical and chemical properties of some elements like, Eka-Boron. Eka-Aluminium and Eka-Silicon. After the discoveries of these elements, their properties were same as predicted by Mendeleev. They have been named as Scandium (Eka-Boron), Gallium (Eka-Aluminium) and Germanium (Eka-Silicon).

the elements of that group.

## MENDELEEV'S TABLE

| ROW | Group 1 | Group II | Group III | Group IV | Group V | Group VI | Group VII | Group VIII |
|---|---|---|---|---|---|---|---|---|
| 1 | H = 1 | | | | | | | |
| 2 | Li = 7 | Be = 9 | B = 11 | C = 12 | N = 14 | O = 16 | F = 19 | Ne = 20 |
| 3 | Na = 23 | Mg = 24 | Al=27 | Si=28 | P=31 | S=32 | Cl=35.5 | Ar = 40 |
| 4 | K= 39 | Ca=40 | — =44 | Ti=48 | B=51 | Cr=52 | Mn=55 | Fe=56,Co=59.9 Ni=58.6,Cu=63 |
| 5 | Cu=63 | Zn=65 | — =68 | — =72 | As=75 | Se=78 | Br=80 | |
| 6 | Rb=85 | Sr=87 | — =88 | Zr=90 | Nh=94 | Mo=96 | — =100 | Ru=104,Rh-104 Pb=106,Ag-108 |
| 7 | (Ag=108) | Cd=112 | In=113 | Sn=118 | Sb=122 | Te=127.5 | I =127 | |
| 8 | Cs=133 | Ba=137 | Di=138 | Ce=140 | | | | |
| 9 | | | | | | | | |
| 10 | | | Er=178 | La=180 | Ta=182 | W=184 | | Os=195, Ir=197 Pt=198 |
| 11 | (Au=199) | Hg=200 | Tl=204 | Pb=207 | Bi=208 | | | |
| 12 | | | | Th=231 | | U=240 | | |

### Discrepancies (Defects) of Mendeleev's Periodic Table:

i. There are some pairs of elements i.e. elements of higher atomic masses placed before elements of lower masses i.e.
   a) Argon (40) placed before Potassium (39).
   b) Tellurium (127.5) placed before Iodine (127).

ii. This table does not give any indication about the position of isotopes.

iii. Mendeleev's table does not give any idea of the structure of atoms.

iv. Dissimilar elements placed in the same group i.e. Alkali metals (Li. Na, K) were placed with coinage metals (Cu, Ag, Au)

v. Lanthanides and Actinides were assigned the same place in the periodic table which goes against the periodic law.

vi. The change in the atomic masses of two successive elements is not constant. Hence, it is not possible to predict the number of missing elements by knowing the atomic masses of two known elements.

### Conclusion:

On the basis of the above discussion, we can conclude that the classification of elements on the basis of atomic masses was not correct. In other words, atomic mass is not a fundamental property of an element.

## 4.6. MODERN PERIODIC LAW:

In 1914, **Bohr**, **Werner** and **Bury** proposed the modern periodic law after the concept of atomic number given by **Moseley**. This law removed the defects in Mendeleev's periodic table:

**Statement:**

*"... of elements are the periodic function of their atomic numbers."*

After the discovery of proton, it was found that the properties of elements depend upon the number of protons and their electronic configuration (electronic arrangement).

## PERIODS:

***"The horizontal rows in the modern periodic table are called periods."***

The period number shows the number of shells in the atom of the element. There are seven periods in the ***Modern Periodic Table*** or ***Long Form***. Following are the details of seven different periods:

### 1st Period:

The first period consists of two elements, Hydrogen (H) and Helium (He). Hydrogen contains only one proton in its nucleus, so its atomic number is 1. Its electronic configuration is K=1 while the next element is Helium which has 2 protons in its nucleus, so its atomic number is 2. Its electronic configuration is K = 2.

K-shell can not accommodate more than 2 electrons. Hence, Helium is placed in VIII or zero group. Helium shows extraordinary stability and inertness due to filled shell.

### Second and Third Period:

The second and third periods are called short periods. There are eight elements present in each period. Each element is placed in the respective group according to its electronic configuration. The elements included in these periods are:

**2nd Period:** ${}^{7}_{3}Li$, ${}^{9}_{4}Be$, ${}^{11}_{5}B$, ${}^{12}_{6}C$, ${}^{14}_{7}N$, ${}^{16}_{8}O$, ${}^{19}_{9}F$, ${}^{20}_{11}Ne$

**3rd Period:** ${}^{23}_{11}Na$, ${}^{24}_{12}Mg$, ${}^{27}_{13}A\ell$, ${}^{32}_{14}Si$, ${}^{31}_{15}P$, ${}^{32}_{16}S$, ${}^{35.5}_{17}C\ell$, ${}^{40}_{18}Ar$

### Fourth and Fifth Period:

### 4th Period:

The fourth period is called the long period. It includes eighteen elements, out of which, eight are called normal elements and the remaining ten are called Transition elements.

**Normal Elements:** ${}_{19}K$, ${}_{20}Ca$, ${}_{31}Ga$, ${}_{32}Ge$, ${}_{33}As$, ${}_{34}Se$, ${}_{35}Br$, ${}_{36}Kr$,

**Transition Elements:** ${}_{21}Sc$, ${}_{22}Ti$, ${}_{23}V$, ${}_{24}Cr$, ${}_{25}Mn$, ${}_{26}Fe$, ${}_{27}Co$, ${}_{28}Ni$, ${}_{29}Cu$, ${}_{30}Zn$

### 5th Period:

The fifth period is also called a long period. It consists of eight normal elements and ten transition elements.

**Normal Elements:** ${}_{37}Rb$, ${}_{38}Sr$, ${}_{49}In$, ${}_{50}Sn$, ${}_{51}Sb$, ${}_{52}Te$, ${}_{53}I$, ${}_{54}Xe$

**Transition Elements:** ${}_{39}Y$, ${}_{40}Zr$, ${}_{41}Nb$, ${}_{42}Mo$, ${}_{43}Tc$, ${}_{44}Ru$, ${}_{45}Rh$, ${}_{46}Pd$, ${}_{47}Ag$, ${}_{48}Cd$

## 6th Period:

The sixth period is the longest period and it consists of 32 elements. It consists of eight normal elements, ten outer transition elements and fourteen inner transition elements (Lanthanides or Rare Earth Metals).

**Normal Elements:** $_{55}Cs$, $_{56}Ba$, $_{81}Tl$, $_{82}Pb$, $_{83}Bi$, $_{84}Po$, $_{85}At$, $_{86}Rn$

**Outer Transition:** $_{57}La$, $_{72}Hf$, $_{73}Ta$, $_{74}W$, $_{75}Re$, $_{76}Os$, $_{77}Ir$, $_{78}Pt$, $_{79}Au$, $_{80}Hg$

**Inner Transition (Lanthanides):**

$_{58}Ce$, $_{59}Pr$, $_{60}Nd$, $_{61}Pm$, $_{62}Sm$, $_{63}Eu$, $_{64}Gd$, $_{65}Tb$, $_{66}Dy$, $_{67}Ho$, $_{68}Ex$, $_{69}Tm$, $_{70}Yb$, $_{71}Lu$

## 7th Period:

The seventh period is incomplete. It contains two elements as normal elements which fourteen inner transition elements are called Actinides. Actinides are radioactive elements. Some of them have been prepared artificially.

**Normal Element:** $_{87}Fr$, $_{88}Ra$.

**Outer Transition:** $_{89}Ac$, $_{104}Unq$, $_{105}Unp$, $_{106}Unh$, $_{107}Uns$, $_{108}Uno$, $_{109}Une$, $_{110}Unu$

**Inner Transition (Actinides):**
$_{90}Th$, $_{91}Pa$, $_{92}U$, $_{93}Np$, $_{94}Pu$, $_{95}Am$, $_{96}Cm$, $_{97}Bk$, $_{98}Cf$, $_{99}E$, $_{100}Fm$, $_{101}Md$, $_{102}No$, $_{103}Lr$

| Number of period | No of elements | Starts from | Ends at |
|---|---|---|---|
| 1st | 2 | Hydrogen (H) | Helium (He) |
| 2nd | 8 | Lithium (Li) | Neon (Ne) |
| 3rd | 8 | Sodium (Na) | Argon (Ar) |
| 4th | 18 | Potassium (K) | Krypton (Kr) |
| 5th | 18 | Rubidium (Rb) | Xenon (Xe) |
| 6th | 32 | Cesium (Cs) | Radon (Rn) |
| 7th | 24 | Francium (Fr) | ----------- |

## GROUPS:

***"The vertical columns in the periodic table are called Groups."***

The group number shows the number of electrons in the valence shell. Element with similar outer electronic configuration show similar properties and are placed in the same group. Group number is also called **valence number**.

The periodic table consists of eight Groups. They are further sub-divided into two sub-groups. Normal (representative) elements are kept in "A" sub-group and Transition elements in "B" sub-group.

Light Metals

Heavy Metals

Non-metals

| PERIOD | IA | IIA | IIIB | IVB | VB | VIB | VIIB | VIII | VIII | VIII | IB | IIB | IIIA | IVA | VA | VIA | VIIA | VIII(0) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | 1 H 1.008 | | | | | | | | | 2 He 4.0 |
| 2 | 3 Li 7.0 | 4 Be 9.0 | | | | | | | | | | | [redacted] | 6 C 12.01 | 7 N 14.01 | 8 O 16.00 | 9 F 19.09 | 10 Ne 20.0 |
| 3 | 11 23.00 | 12 24.0 | | | | | | | | | | | 27.0 | [redacted] | 31.0 | 32.00 | Cl 35.5 | Ar 40.0 |
| 4 | 19 K 39.0 | 20 Ca 40.08 | 21 Sc 45.10 | 22 Ti 47.90 | 23 V 50.95 | 24 Cr 52.01 | 25 Mn 54.93 | 26 Fe 55.83 | 27 Co 55.9 | 28 Ni 58.09 | 29 Cu 63.5 | 30 Zn 65.5 | 31 Ga 69.72 | 32 Ge 72.60 | [redacted] | 34 Se 78.96 | 35 Br 80.0 | 36 Kr 83.70 |
| 5 | 37 Rb 85.48 | 38 Sr 87.63 | 39 Y 88.92 | 40 Zr 91.27 | 41 Nb 92.91 | 42 Mo 95.95 | 43 Tc 99.00 | 44 Ru 101.7 | 45 Rh 102.9 | 46 Pd 106.7 | 47 Ag 107.9 | 48 Cd 112.4 | 49 In 114.8 | 50 Sn 118.7 | 51 Sb 121.5 | [redacted] | 53 I 127.0 | 54 Xe 131.0 |
| 6 | 55 Cs 132.9 | 56 Ba 137.4 | 57 La 138.9 | 72 Hf 178.6 | 73 Ta 180.9 | 74 W 183.9 | 75 Re 186.3 | 76 Os 190.2 | 77 Ir 193.1 | 78 Pt 195.2 | 79 Au 197.2 | 80 Hg 200.6 | 81 Tl 204.4 | 82 Pb 207.2 | 83 Bi 209.0 | 84 Po 210 | [redacted] | 86 Rn 222 |
| 7 | 87 Fr 223 | 88 Ra 226.1 | 89 Ac 227 | 104 Unq | 105 Unp | 106 Unh | 107 Uns | 108 Uno | 109 Une | 110 Unn | | | | | | | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| "LANTHANIDES" | 57 La 138.9 | 58 Ce 140.1 | 59 Pr 140.9 | 60 Nd 144.3 | 61 Pm 146 | 62 Sm 150.4 | 63 Eu 152.0 | 64 Gd 156.5 | 65 Tb 159.2 | 66 Dy 162.5 | 67 Ho 164.9 | 68 Er 167.2 | 69 Tm 169.4 | 70 Yb 173.0 | 71 Lu 175.0 |
| "ACTINIDES" | 89 Ac 227 | 90 Th 232.1 | 91 Pa 231 | 92 U 238.1 | 93 Np 237 | 94 Pu 239.1 | 95 Am 243.1 | 96 Cm 247.1 | 97 Bk 247.1 | 98 Cf 252.1 | 99 Es 252.1 | 100 Fm 257.1 | 101 Md 256.1 | 102 No 259.1 | 103 Lw 259.1 |

## Group I-A The Alkali Metals (Lithium Family):

This group consists of Lithium, Sodium, Potassium, Rubidium, Cesium and Francium, called the Alkali Metals.

| |
|---|
| $_3$Li |
| $_{11}$Na |
| $_{19}$K |
| $_{37}$Rb |
| $_{55}$Cs |
| $_{87}$Fr |

1. They are light, soft and highly reactive metals. Francium ~~is~~ radioactive element.
2. They contain only one electron in their outermost shell.
3. They form monovalent or univalent cations (+ve ions) by loss of electron.
4. They form ionic compounds.
5. Reactivity (Metallic character) increases in the group from top to bottom but ionization potential decreases.

**Note:** Alkali is an Arabic word which means "ashes". Compounds of these metals were btained from wood ashes and they form water soluble bases (Alkalies).



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## Group II-A The Alkaline Earth Metals (Beryllium Family):

This group consists of Beryllium, Magnesium, Calcium, Strontium, Barium and Radium, called the Alkaline Earth Metals.

| |
|---|
| $_4$Be |
| $_{20}$Ca |
| $_{38}$Sr |
| $_{56}$Ba |
| $_{88}$Ra |

1. They are light, hard and moderately reactive metals. Radium is
2. They contain two electrons in their outermost shell.
3. They form divalent cations (+ve ions) by loss of two electrons.
4. They form ionic compounds.
5. Reactivity (Metallic character) increases in the group from top to bottom but ionization potential decreases.

Note: These elements are found as minerals. Their silicates, oxides and hydroxides are strongly basic. Therefore these elements are called Alkaline Earth Metals.

## Group III-A The Boron Family:

This group consists of Boron, Aluminium, Gallium, Indium and Thallium called Boron family.

| |
|---|
| $_5$B |
| $_{13}$Aℓ |
| $_{31}$Ga |
| $_{49}$In |
| $_{81}$Tℓ |

1. They contain three electrons in their outermost shell. They are trivalent.
2. They are also reactive chemically and are highly electropositive.
3. They form covalent bonds like non metals due to small size, high charge and large values of ionization potential.
4. Reactivity (Metallic character) increases in the group from top to bottom but ionization potential decreases.

Note: Boron is metalloid, while the other members of this group are metals.

## Group IV-A The Carbon Family:

This group consists of Carbon, Silicon, Germanium, Tin (Stannum), Lead (Plumbum) called Carbon family.

| |
|---|
| $_6$C |
| $_{14}$Si |
| $_{32}$Ge |
| $_{50}$Sn |
| $_{82}$Pb |

1. They contain four electrons in their outermost shell. They are tetravalent.
2. They show non-metallic characteristics.
3. Carbon and Silicon form covalent bonds only by sharing their four electrons. Tin and Lead form ionic bonds by losing their electrons from the valence shell.
4. Electronegativity decreases in the group from top to bottom (C to Pb).

Note: Carbon is a non metal: **Silicon** is **metalloid**. while the other members of this group are metals. Carbon has two allotropes. (Different forms of an element having same chemical properties and different physical properties due to different structures are called Allotropes and the phenomenon is called **Allotropy**.



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## Group V-A The Nitrogen Family:

This group is consists of Nitrogen, Phosphorus, Arsenic, Antimony and Bismuth called the Nitrogen family.

1. They contain five electrons in their outermost shell. They require three
2. They are trivalent.
3. They form covalent compounds due to small atomic size and large ionization potential. Antimony (Sb) and Bismuth (Bi) form ionic bond only and form $Sb^{3+}$ and $Bi^{3+}$ cations (+ve ions).
4. They have high ionization potentials and high electronegativity. I.P. and E.N. decrease down the group.

| |
|---|
| $_{7}N$ |
| $_{33}As$ |
| $_{51}Sb$ |
| $_{83}Bi$ |

**Note:** Except Nitrogen, all exist in more than one allotropic forms. Nitrogen and Phosphorus are non metals; **Arsenic is metalloid** while Antimony and Bismuth are metals.

## Group VI-A The Oxygen Family:

This group consists of Oxygen, Sulphur, Selenium, Tellurium and Polonium called the Oxygen family.

1. They contain six electrons in their outermost shell. They require two electrons to complete their valence shell.
2. They form divalent anions (-ve ions) by gain of two electrons.
3. They form ionic compounds when they react with metals while they form covalent compounds when they react with non metals.
4. They have high ionization potentials and high electronegativity. I.P. and E.N. decrease down the group.

| |
|---|
| $_{8}O$ |
| $_{16}S$ |
| $_{34}Se$ |
| $_{52}Te$ |
| $_{84}Po$ |

**Note:** Oxygen, Sulphur and Selenium are non-metals, **Tellurium is metalloid** and Polonium (Po) is radioactive element.

## Group VII-A The Halogen Family:

This group consists of Fluorine, Chlorine, Bromine, Iodine and Astatine, called the Halogen family (Halogen means *salt-former*).

1. They contain seven electrons in their outermost shell and require only one electron to complete their valence shell.
2. They form monovalent anions (-ve ions) by gain of one electron to produce halide ion ($X^{1-}$) $F^{1-}$, $Cl^{1-}$, $Br^{1-}$, $I^{1-}$.
3. They are found as diatomic molecule.
4. They form ionic compounds when they react with metals while they form covalent compounds when they react with non metals.
5. They are very active non-metals so they cannot exist in Free State.
6. Halogens are highly electronegative elements and their electronegativity decreases in the group from Fluorine to Iodine.

| |
|---|
| $_{9}F$ |
| $_{17}Cl$ |
| $_{35}Br$ |
| $_{53}I$ |
| $_{85}At$ |

Note: Fluorine and Chlorine are gases; Bromine is liquid while Iodine and Astatine are solid. Astatine is radioactive element. **Fluorine has the highest value of** E.N. i.e **4.0.**

## Group VIII-(Zero) The Noble Gases:

| |
|---|
| $_{2}He$ |
| $_{10}Ne$ |
| $_{18}Ar$ |
| $_{36}Kr$ |
| $_{54}Xe$ |
| $_{86}Rn$ |

This group consists of Helium, Neon, Argon, Krypton, Xenon and Radon, called the Noble (Inert) gases. They are also called Zero Group.

1. Their outermost shells are completely filled so they are stable and non-reactive (inert) chemically.
2. They are highly stable so they do not form their compounds.
3. They are monoatomic gases with low boiling points.
4. All Noble gases are present in the atmosphere e.g. Argon is present to the extent of 1% in the atmosphere by volume. Radon is radioactive.

## TYPES OF ELEMENTS:

### 1. NOBLE (INERT) ELEMENTS:

The elements which have completely filled valence shells are called Noble (Inert) elements. They have been placed in group VIII (0) in the modern periodic table.

e.g. He, Ne, Ar, Kr, Xe and Rn.

### 2. REPRESENTATIVE (NORMAL) ELEMENTS:

The elements which have incomplete valence shells are called representative (Normal) elements. They have been placed in groups IA to VIIA in the modern periodic table

e.g. H, Li, Na, F, Cl, etc.

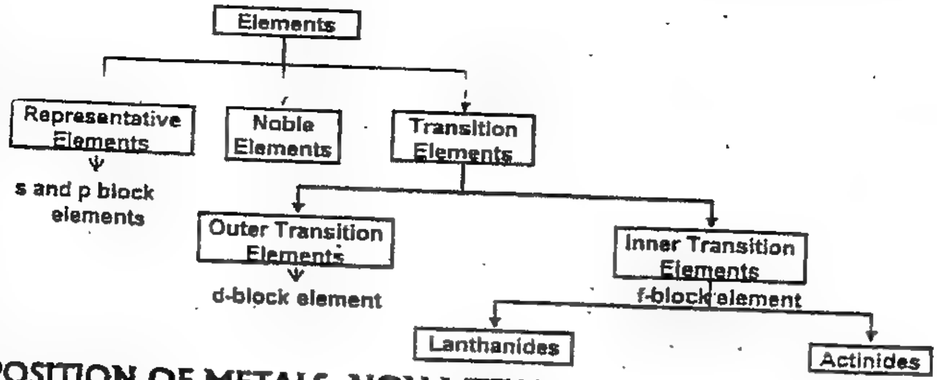
They have incomplete inner electron shells and are characterized by their variable valencies and show similar behaviours.

### 3. TRANSITION ELEMENTS:

The elements which have incomplete valence as well as penultimate shells are called transition elements. They have been placed in groups IIIB to IIB in the modern periodic table. Following are the properties of transition elements:

1. They show variable valencies. ($Cu^{+}$, $Cu^{2+}$, $Fe^{2+}$, $Fe^{3+}$, etc).
2. Their solutions are coloured in nature. ($CuSO_4$ Blue, $FeSO_4$ Light green)
3. All transition elements are metals, in which the bonds between the atoms are very strong and they have high melting points.
4. They form complex compounds.
5. The outer transition elements are also called ***d-block elements***. They have incomplete penultimate shell as well as incomplete valence shell.

6. The inner transition elements are also called *f-block elements*. They have incomplete inner shell and valence shell. This type includes two series of *rare earth* elements: Lanthanides and Actinides.




## POSITION OF METALS, NON-METALS AND METALLOIDS IN THE PERIODIC TABLE:

### Metals:

They are the donors of electrons. They are also called reducing agents.

| Non-metals | | | | | 2 He 4.0 |
|---|---|---|---|---|---|
| | 6 C 12.01 | 7 N 14.01 | 8 O 16.00 | 9 F 19.00 | 10 Ne 20.1 |
| 13 Al 27.0 | | 15 P 31.0 | 16 S 32.0 | 17 Cl 35.5 | 18 Ar 40.0 |
| 31 Ga 69.72 | 32 Ge 72.60 | | 34 Se 78.96 | 35 Br 80 | 36 Kr 83.70 |
| 49 In 114.8 | 50 Sn 118.7 | 51 Sb 121.6 | | 53 I 127.0 | 54 Xe 131.0 |
| 81 Tl 204.4 | 82 Pb 207.2 | 83 Bi 209.0 | 84 Po 210 | | 86 Rn 222 |

### Properties of Metals:

1. Metals are good conductors of heat and electricity.
2. They form cations (+ve ions) because they are electro positive.
3. They form basic oxides.
4. They have shiny surfaces (lustre).
5. They have less values of their electronegativities.
6. They are malleable (i.e. can be spread out into sheets).
7. They are ductile (i.e. they can be drawn into wires).

### Position of Metals:

1. Group IA (except Hydrogen), IIA, IIIA, the transition elements IIIB-IIB. Actinide and Lanthanide series are all classified as metals.
2. Below the shaded part (staircase) in the periodic table, all elements are metals.

### Non Metals:

They are the acceptors of electrons. They are also called oxidizing agents.

### Properties of Non-Metals:

1. Non-metals are bad conductors (insulator) of heat and electricity.
2. They form anions (–ve ions) because they are electronegative.
3. They form acidic oxides.
4. They have dull surfaces.
5. They have high values of their electronegativities.
6. Solid non metals are brittle.
7. Most of them are gases.

## Position of Non-Metals:

1. Majority of elements of p-block in groups III-A, IV-A, V-A, VI-A and VII-A are non metals.
2. ·have the shaded parts (stair case) in the periodic table. all elements are non metals.

## METALLOIDS:

The elements which show the properties of both metals and non metals are called Metalloids.

They form amphoteric oxides (acidic as well as basic).

## Position of Metalloids:

The elements in the shaded parts (staircase) in periodic table, are metalloids.

i) Boron (B) in III-A   ii) Silicon (Si) in IV-A   iii) Arsenic (As) in V-A

iv) Tellurium (Te) in VI-A   v) Astatine (At) in VII-A

## SPECIFIC PHYSICAL PROPERTIES OF ATOM:

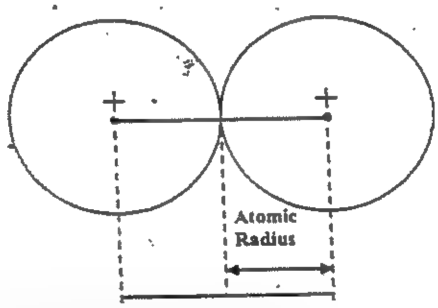
### 1) ATOMIC RADIUS:

***"Half of the distance between the nuclei of two adjacent atoms of an element is called Atomic Radius."***

**Unit of Measurement:**

It is measured in Angstrom Unit. It is represented by $A^0$.

$1A^0 = 10^{-10}m$ *OR* $1A^0 = 10^{-8}cm$




**i) Group Trend:**

Atomic radius **increases** downward in a group due to increase in the number of shells (new shells) and the power of the nucleus to attract electrons decreases.

| | Increase in Atomic Radius ↓ |
|---|---|
| Be 1.12 | |
| Mg 1.36 | |
| Ca 1.97 | |
| Sr 2.15 | |
| Ba 2.22 | |

**ii) Periodic Trend:**

Atomic radius **decreases** from left to right in a period due to increase in nuclear charge (number of protons) in the nucleus which increases the force of attraction on the electron. As a result the size of the atom reduces.

| Na | Mg | Al | Si | P | S | Cl |
|---|---|---|---|---|---|---|
| 1.51 | 1.36 | 1.25 | 0.77 | 0.70 | 0.66 | 0.64 |

→ **Decrease in Atomic Radius**

## 2) IONIZATION ENERGY (I.E. OR I.P.):

*"The amount of energy required to remove electron(s) from the valence shell of an atom in gaseous state is called Ionization energy or Ionization potential."*

**Unit of Measurement:**

It is measured in Kilo Joule/mole. (KJ/mol) OR electron volt per atom (ev/atom)

$H_{(g)}$ + Energy ⟶ $H^{+} + e^{-}$ I.E = [illegible]

**Group Trend:**

Ionization energy (I.E. or I.P.) **decreases** downward in a group due to increase in the number of shells (new shell) and the power of the nucleus to attract the electrons decreases.

**ii) Periodic Trend:**

Ionization energy (I.E. or I.P.) **increases** from left to right in a period, due to increase in nuclear charge (number of protons) in the nucleus which increases the force of attraction on electrons.

## 3) ELECTRON AFFINITY:

***"The energy change which occurs during the absorption (gain) of electron by an atom in the gaseous state is called Electron Affinity."***

**Unit of Measurement:**

It is measured in KJ/mol or electron volt (ev/atom).

Electron affinity (E.A.) of 1st electron is negative i.e. Energy is released.

Electron affinity (E.A.) of 2nd electron is positive i.e. Energy is absorbed because energy overcomes the repulsion between the negative ion and electron as shown below:

$O_{(g)} + e^{-} \longrightarrow O^{-}$ E.A = - 142 KJ/mol (Exothermic)

$O^{-} + e^{-} \longrightarrow O^{2-}$ E.A = +780 KJ/mol (Endothermic)

**Group Trend:**

Electron affinity (E.A.) **decreases** downward in a group due to increase in the number of shells (new shell) and the power of the nucleus to attract the electrons decreases.

Fluorine **(F)** shows low electron affinity because due to its very small atomic size it does not accept electron easily.

| ELEMENT | ELECTRON AFFINITY (KJ/mol) |
|---|---|
| F | -333 |
| Cl | -348 |
| Br | -324 |
| I | -295 |

**Periodic Trend:**

Electron affinity (E.A.) **increases** from left to right in a period, due to increase in nuclear charge (number of protons) in the nucleus which increases the force of attraction on electrons.

## 4) ELECTRONEGATIVITY:

*"The tendency of an atom in a molecule to attract a shared pair of electrons towards itself is called Electronegativity."*

**Unit of Measurement:**

It has *no unit* for measurement. It is only a number. Linus Pauling calculated the electronegativities of different elements, taking **Fluorine** as standard with its E.N. = 4.0

### Group Trend:

Electronegativity (E.N.) **decreases downward** in a group due to increase in the number of shells (new shell) and the power of the nucleus to attract the electrons decreases.

### Periodic Trend:

Electronegativity (E.N.) **increases** from left to right in a period. due to increase in nuclear charge (number of protons) in the nucleus which increases the force of attraction on electrons.

**Note:** Fluorine (F) has the highest E.N. **(4.0)** while Cesium (Cs) has the lowest E.N. **(0.6)**

## EXERCISE

**1. Fill in the blanks:**

i) The rule of triads was introduced by __________.

ii) The repetition of properties after regular intervals is called __________.

iii) The longest period is __________ period and contains ________ elements.

iv) The elements which contain both metallic and non-metallic characteristics are called __________.

v) The long form of periodic table contains _______ groups and _______ periods.

vi) According to Mendeleev, the properties of the elements are the periodic functions of their __________.

| | | | | | |
|---|---|---|---|---|---|
| I | Dobereiner | ii | Periodicity | iii | $6^{th}$, 32 |
| Iv | Metalloids | v | 8, 7 | vi | Atomic weight |

**2. Tick True *OR* False in the following statements:**

i) Mendeleev put forward his periodic law in 1856.

ii) The first period contains two elements, Hydrogen and Helium.

iii) The longest period in the periodic table is $7^{th}$ period.

iv) Lanthanides and Actinides are d-block elements.

v) Down the group, electronegativity increases with increasing atomic number.

vi) The law of octaves was introduced by John Newlands.

vii) $^{7}Li$, $^{23}Na$ and $^{39}K$ form a triad.

ANSWERS: (i) F. (ii) T. (iii) F. (iv) F.
(v) F. (vi) T. (vii) T.

**3. Pick up the correct answer: (Multiple Choice Questions):**

i) Mendeleev's periodic table contained __________ periods.
(7, 8, 12, 10)

ii) The incomplete period in the periodic table is __________.
(7, 6, 3 1)

iii) The most reactive metal is __________.
(Na, Cu, Fe, Ca)

iv) The only liquid metal is __________.
(Molybdenum, Gold, Mercury, Bromine)

v) Lothar Meyer's curve included about __________ elements.
(Thirty, forty, fifty six, sixty two)

vi) To which family does Ga Belong?
(Boron, Carbon, Nitrogen, Fluorine)

vii) The elements of VII-A group are known as __________.
(Halogens, Lanthanides, Actinides)

viii) Which pair of ...

a) K, Cr  b) Cu, Ca
c) F,Cl  d) N, O

ANSWER: (i) 12. (ii) 7. (iii) Na. (iv) Mercury.
(v) Fifty six. (vi) Boron. (vii) Halogens. (viii) F, Cl.

**4. Write answer to the following questions:**

i) Define the following:

a) Dobereiner's rule of triad **(Answer on page # 3)**
b) Periodicity **(Answer on page # 5)**
c) Modern periodic law **(Answer on page # 7)**
d) Electronegativity **(Answer on page # 15)**

ii) An element contains two shells and its outer shell contains five electrons. To which group does the element belong in the periodic table? Name the element. Predict its period.

ANSWER:

Its electronic configuration is $K^2L^5$. It means that,

- Its name is Nitrogen (atomic number 7 = $K^2L^5$)
- Its group number is V-A (outer shell contain five electrons)
- Its period is $2^{nd}$ (contain only two shells)

iii) State Mendeleev's periodic law. Describe Mendeleev's periodic table. Write the advantages and disadvantages of Mendeleev's periodic table.

**(Answer on page # 5 and 6)**

iv) Explain Newland's law of Octaves. How did this law provide the larger scope for the classification of the elements?

**(Answer on page # 4)**

v) Which pair of elements is chemically similar?

(a) K, Cr (b) Cu, Ca (c) ***F, Cl*** (d) N, O

vi) What do you understand by long form of periodic table? Explain some of its applications.

**(Answer on page # 7)**

vii) Discuss some of the physical properties of the elements which exhibit periodicity.

ANSWER:

Following are some physical properties of elements which exhibit periodicity.

**a) Similar Properties:**

The elements in a group show similar properties due to their similar electronic configurations.

**b) Regular Gradation:**

A regular gradation in physical and chemical properties of elements in a group is observed due to gradual change in their electronegativities and atomic sizes.

**c) Size of Atom (Atomic Radius):**

The atomic radius increases downward in the group with increase in the number of shells (new shell).

**d) Metallic Character:**

Metallic character (electro-positivity) increases downward in the group with increase in atomic size. Cesium is the most electropositive and Lithium the least among alkali metals.

**e) Electronegativity:**

Electronegativity decreases downward in the group with increase in atomic size. Fluorine is the most electronegative and Iodine the least among halogens.

**f) Ionization Energy:**

Ionization energy decreases downward in the group with increase in atomic size.

viii) Elements having eight valence electrons are known as:

*(a) Noble or inert gases* (b) Halogens

(c) Nitrogen family (d) Transition elements

ix) How does the modern periodic law differ from Mendeleev's periodic law? Explain clearly groups and periods in the modern periodic table.

**(Answer on page # 6 and 7)**

x) What do you understand by representative and transition elements?

**(Answer on page # 12)**

xi) Discuss the following physical properties of the elements.

(a) Atomic Radius **(Answer on page # 14)**

(b) Ionization energy **(Answer on page # 14)**

(c) Electron affinity **(Answer on page # 15)**

(d) Electronegativity **(Answer on page # 15)**

SESSION 2016-2017



PRACTICAL CENTRE KARACHI

# CLASS-IX

# CHEMISTRY

## Chapter # 5

## CHEMICAL BONDING

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# CHEMICAL BONDING 5

*"The attractive force which binds two or more atoms of the same or different elements is called a Chemical bond."*

*"The force of attraction which holds unstable atoms together in the form of a molecule or ions in a crystal is called chemical bond."*

Chemical bond is an example of ***intra molecular force***. Intra molecular force joins unstable atoms to form a molecule.

## Reason for Bonding (Formation of Chemical Bond):

The atoms of noble gases (Group VIII) have their outermost shells completely filled but rest of the elements need to complete their outermost shells. This necessity leads Chemical Bonding.

Atoms of different elements tend to acquire their octet (eight electrons) or duplet (two electrons) in the outermost shell in different ways. They may tend to:

(1) Lose electrons. (2) Gain electrons. (3) Share electrons.

## Types of the Chemical Bond:

There are two main types of chemical bonds:

(1) Ionic bond (2) Covalent bond

## IONIC BOND OR ELECTROVALENT BOND:

*"The chemical bond formed by the complete transference of one or more electrons between two or more atoms is called Ionic Bond or electrovalent bond."*

*OR*

*"The force of attraction which holds the oppositely charged ions together is called an ionic bond or electrovalent bond".*

### Explanation:

When a metal reacts with a non metal, an ionic bond is formed. Metals have less value of their electronegativities than non metals. So the metal atom releases its electron(s) equal to its valency from its outermost shell while the non metal atom gains the electrons in its valence shell. As a result, positive (+ve) and negative (−ve) ions are formed respectively.

These oppositely charged ions are then held together by an electro-static force of attraction. This force of attraction is called electrovalent or ionic bond.

### Example #1: Formation of Sodium chloride (NaCl)

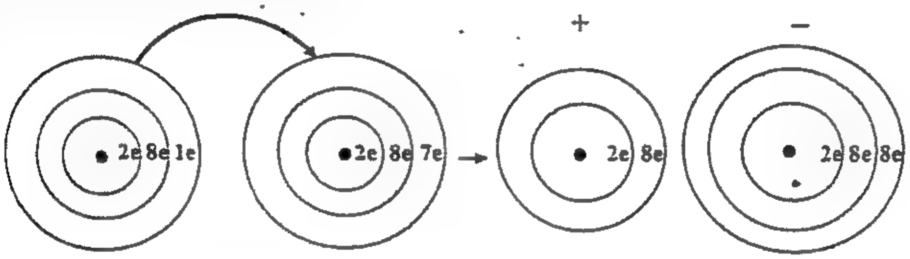
Sodium has one electron in its valence shell. So, it loses one electron and $Na^+$ (sodium ion) is formed. Chlorine atom has seven electrons in its valence shell. So, it picks the electron and $Cl^-$ (Chloride ion) is formed. In this way, both ions acquire eight electrons in their outermost shells.

$$\underset{(K^2L^8M^1)}{Na} \longrightarrow \underset{(K^2L^8)}{Na^+} + e^-$$

$$\underset{(K^2L^8M^7)}{Cl + e^-} \longrightarrow \underset{(K^2L^8M^8)}{Cl^-}$$

$$Na^+ + Cl^- \longrightarrow NaCl$$

These oppositely charged ions are held together by electrostatic force of attraction. In this way, Sodium chloride salt is formed.




Na Cl $Na^+$ $Cl^-$

**Example # 2: Formation of Magnesium oxide (MgO)**

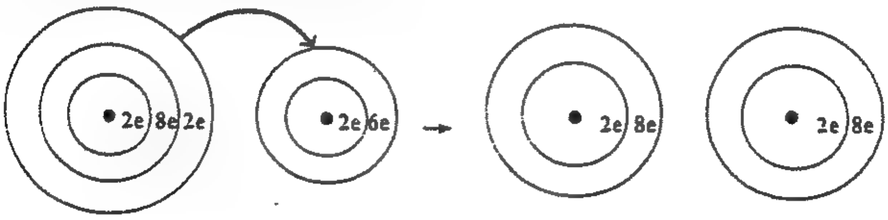
Magnesium has two electrons in its valence shell. So, it loses two electrons and $Mg^{+2}$ (magnesium ion) is formed while Oxygen atom has six electrons in its valence shell. So it picks the electrons and $O^{2-}$ (oxide ion) is formed. In this way, both ions acquire eight electrons in their outermost shells.

$$\underset{(K^2L^8M^2)}{Mg} \longrightarrow 2e^- + \underset{(K^2L^8)}{Mg^{+2}} \quad \textbf{(magnesium ion)}$$

$$\underset{(K^2L^6)}{O + 2e^-} \longrightarrow \underset{(K^2L^8)}{O^{2-}} \quad \textbf{(oxide ion)}$$

$$Mg^{2+} + O^{2-} \longrightarrow MgO \quad \textbf{(magnesium oxide)}$$

These oppositely charged ions are held together by electrostatic force of attraction. In this way, Magnesium oxide is formed.




Mg O $Mg^{2+}$ $O^{2-}$

**Note: If the difference of E.N. between the bonded atoms is 1.7 or more, the bond is ionic bond.**

## Properties of Ionic Compounds:

1. Ionic compounds are made up of oppositely charged ions with the strongest bonding force, that is why they are crystalline solids.
2. They have high melting and boiling points.
3. They are soluble in water (polar solvents) but insoluble in non-polar solvents.
4. They are non-volatile.
5. [illegible] aqueous solution due to free movement of the ions, but they are bad conductors in the solid state as the ions are not free to move.

## Effect of Ionization Energy on Ionic Bond:

*"The amount of energy which is required to remove electron(s) from the valence shell of a metal atom in gaseous state is called ionization energy."*

Elements of group I-A and II-A have low ionization energies so they lose electron(s) more easily to form *Cations*. Hence, these metals have the strongest tendency to form ionic bonds with other elements (non-metals).

## Effect of Electronegativity on Ionic Bond:

*"The tendency of an atom to attract electrons is called electronegativity."*

Elements of group VI-A and VII-A have high values of electronegativity. They gain electron(s) more easily to form *Anions*. Hence, these non-metals have the strongest tendency to form ionic bonds with other elements (metals).

## THE COVALENT BOND:

*"The chemical bond formed by the mutual sharing of electrons is called Covalent Bond."*

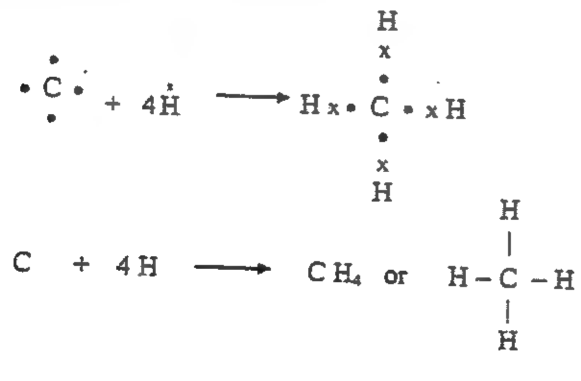
The idea of electron pair bond (covalent bond) was first introduced in 1916 by G. N. Lewis.

### Explanation:

A covalent bond is formed by mutual sharing of electrons between non-metals. It is generally represented by a short straight line (—) between two bonded atoms. Each electron pair is attracted by the nuclei of bonded atoms.

### Example:

In a molecule of Methane, Carbon forms four single covalent bonds with four atoms of Hydrogen. Carbon and Hydrogen atoms get their outer most shells filled.



Note:
x = Electrons of Hydrogen
• = Electrons of Carbon
•x or (–) = Covalent Bond

## TYPES OF COVALENT BOND:

There are three types of covalent bonds:

(1) Single covalent bond (2) Double covalent bond (3) Triple covalent bond

## SINGLE COVALENT BOND:

A covalent bond which is formed by the mutual sharing of one electron pair is called ***single covalent bond.*** It is denoted by single short line (–).
e.g. $H_2$, $F_2$, $Cl_2$, $Br_2$, $I_2$, $H_2O$, $NH_3$, $CH_4$, $C_2H_6$ (ethane), etc.

**Example:**

When two atoms of Chlorine combine then ***one*** electron pair is shared between them. In this way, each atom of Chlorine has obtained eight electrons in its outermost shell.

*OR* Cl + Cl ⟶ $Cl_2$

## DOUBLE COVALENT BOND:

A covalent bond which is formed by the mutual sharing of two electron pairs is called ***double covalent bond.*** It is denoted by two short lines (=).
e.g. $O_2$, $CO_2$, $C_2H_4$ (ethene), etc.

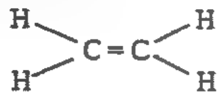
**Example # 1:**

When two atoms of Oxygen combine, then ***two*** electrons each are shared between them. In this way, each atom of Oxygen has obtained eight electrons in its outermost shell.

O + O ⟶ $O_2$

**Example # 2:**

Ethene is an organic compound which is formed when two atoms of Carbon combine then ***two*** electrons each are shared between them while remaining electrons are shared by Hydrogen atoms.



## TRIPLE COVALENT BOND:

A covalent bond which is formed by the mutual sharing of three electron pairs is called ***triple covalent bond.*** It is denoted by three short lines (≡).
e.g. $N_2$, HCN, $C_2H_2$ (ethyne), etc.

**Example # 1:**

When two atoms of Nitrogen combine then ***three*** electrons each are shared between them. In this way, each atom of Nitrogen has obtained eight electrons in its outermost shell.

N + N ⟶ $N_2$

**Example # 2:**

Ethyne is an organic compound which is formed when two atoms of Carbon combine then *three* electrons each are shared between them while remaining electrons are shared by Hydrogen atoms.

$$H-C\equiv C-H$$

## NATURE OF COVALENT BOND:

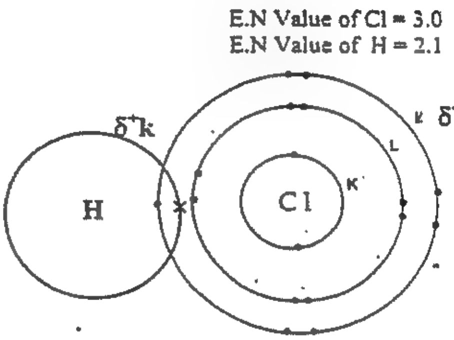
1) Polar covalent bond 2) Non-polar covalent bond

## POLAR COVALENT BOND:

***"The covalent bond formed by the mutual and unequal sharing of electron between the different atoms of non-metals having different electro-negativities is called Polar Covalent Bond."***

**Example:**

$$H\times + \bullet \ddot{\underset{\cdot\cdot}{Cl}}: \longrightarrow H \overset{\times}{\bullet}\ddot{\underset{\cdot\cdot}{Cl}}: \quad \text{or } H^{\delta+}\text{—}Cl^{\delta-}$$




In case of Hydrogen chloride, Chlorine atom is more electronegative than Hydrogen atom. Hence, the shared pair of electrons is attracted more towards the Chlorine atom and Chlorine atom attains slightly negative charge while Hydrogen attains slightly positive charge. That is why HCl is a ***polar compound.***

(Note: $\delta$ = delta, it is used to represent slight or partial charge)

**Explanation:**

When a covalent bond is formed between two dissimilar atoms, the shared pair of electrons is always attracted more towards more electronegative atom. Hence that atom attains slightly negative charge and other atom attains slightly positive charge. These atoms are called negative pole and positive pole respectively. Such compounds are ***Polar Compounds*** and the bonds are called ***Polar Bonds.***

**Note: If the difference of E.N. between the bonded atoms is between 0.4 to 1.7 the bond is polar covalent bond.**

e.g. HCl, $H_2O$, $NH_3$, HF. etc.

## NON POLAR COVALENT BOND:

***"The covalent bond formed by the mutual and equal sharing of electron between the same atoms of non-metals is called Non-polar Covalent Bond."***

**Explanation:**

When a covalent bond is formed between two similar atoms, the shared pair of electrons is always attracted equally between the nuclei of atoms. Hence that molecule is electrically neutral i.e. without any pole (charge) and such substances are called ***Pure Covalent Molecules*** or ***non polar-compounds.***

**Note: If the difference of E.N. between the bonded atoms is 0.0 to 0.4, the bond is Non-polar covalent bond.**

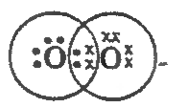
e.g. $H_2$, $F_2$, $Cl_2$, $Br_2$, $I_2$, $N_2$, $O_2$ are examples of **pure covalent molecules** while $CH_4$, $C_2H_6$, $C_2H_4$, $C_2H_2$ are examples of **non-polar covalent molecules.**

1. Covalent compounds are made up of discrete units (molecules) with weak inter molecular forces.
2. They have low melting and boiling points due to weak Van der Wall's forces between the molecules.
3. They are insoluble in water (polar solvent) but soluble in non polar (organic) solvents like petrol, spirit, benzene, ether, carbon tetrachloride etc.
4. They are volatile.
5. They are non-electrolytes. They are bad conductors or insulators because they do not conduct electricity.

## Dot and Cross Models and Lewis Formulae:

Models and formulae are used to express covalent bonding. Sometimes, with the help of dot and cross, sharing of electrons is represented. Lewis also gave a method to represent the sharing, it is called Lewis formula.

### MOLECULAR STRUCTURE OF FEW SUBSTANCES

| METHOD OF REPRESENTATION | HYDROGEN CHLORIDE | OXYGEN |
|---|---|---|
| FORMULAE | HCl | $O_2$ |
| MOLECULAR STRUCTURE | H – Cl | O = O |
| DOT AND CROSS MODEL or LEWIS FORMULA |  |  |
| OCTET RULE |  |  |

## DIFFERENCE BETWEEN IONIC & COVALENT COMPOUND

| IONIC COMPOUND | COVALENT COMPOUND |
|---|---|
| 1. Ionic compounds are usually crystalline solids, hard and brittle. | 1. Covalent compounds exist in all the three states i.e. solid, liquid and gas. |
| 2. Ionic compounds are soluble in polar solvent like water but insoluble in non-polar solvents (petrol, kerosene etc). | 2. Covalent compounds are insoluble in polar solvents like water but soluble in non-polar solvents (petrol, kerosene etc). |
| 3. Ionic compounds have high melting and boiling points. | 3. Covalent compounds have low melting and boiling points. |
| 4. Ionic compounds are non-volatile. | 4. Covalent compounds are mostly volatile. |
| 5. Ionic compounds do not conduct electricity in the solid state but they are good conductors of electricity in the fused state or in aqueous solution. i.e. they are electrolytes. | 5. Pure covalent compounds do not conduct electricity. Only Polar covalent compounds conduct electricity in aqueous solution. i.e. they are non-electrolytes |

## DIPOLE-DIPOLE INTERACTION (DIPOLE-DIPOLE ATTRACTION):

*"The intermolecular force of attraction present between polar molecules is called Dipole-Dipole Interaction."*

In a polar covalent molecule, each atom carries partial positive and partial negative charge so a polar molecule contains *Dipole* (two types of charges). In such bond, partial positive end attracts partial negative end of the neighbouring molecule.

The strength of attraction depends on the difference between the electronegativities of the atoms, which form the polar bond. The greater the difference in E.N value the stronger the polarization of the bond and greater the dipole-dipole interaction.

$$\begin{matrix} H^{\delta+} - & S^{\delta-} & \ldots\ldots & H^{\delta+} - & S^{\delta-} \\ & | & & & | \\ & H^{\delta+} & & & H^{\delta+} \end{matrix} \qquad H^{\delta+} - Br^{\delta-} \ldots\ldots H^{\delta+} - Br^{\delta-}$$

## THE HYDROGEN BOND:

*"The intermolecular force in polar molecules containing Hydrogen atom, covalently bonded to atom of more electronegative elements such as N, O, F, etc. is called Hydrogen Bond."*

OR

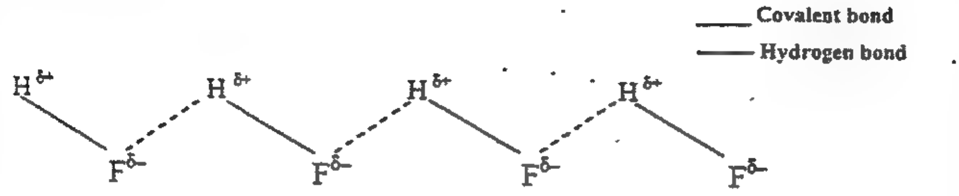
*The dipole - dipole force of attraction between two polar molecules in which Hydrogen atom is present with the partial positive charge, is called hydrogen bond.*

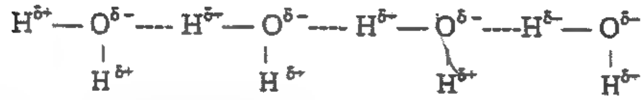
e.g. HF, $NH_3$, $H_2O$, etc.

In the molecule of HF (Hydrogen fluoride), strongest Hydrogen bonding is present where the molecules are held together in long chain.

- Hydrogen bond is not actually a chemical bond but it is a type of ***inter molecular force*** between the polar molecules.

- Hydrogen bond has important effect on the physical properties of compounds like HF, $H_2O$, $NH_3$, etc.




## COORDINATE COVALENT BOND (DATIVE BOND):

***"The bond which is formed by one-sided sharing of lone pair of electrons is called Coordinate Covalent Bond."***

In this type of bond, a lone pair of electrons is provided by an atom or a group of atoms to the other atoms or ions, so it is also called ***Dative Bond.***

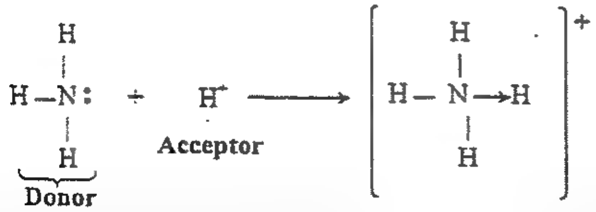
Coordinate covalent bond is indicated by an arrow (→) pointing towards the atom which accepts the electron pair ($NH_3 \rightarrow {}^+H$). The elements of group VA, VIA or VIIA give the lone pair of electrons (Donor).

### Example# 1:

When a Nitrogen atom combines with three Hydrogen atoms to form a molecule of Ammonia, the Nitrogen atom is surrounded by the bonding pairs and a lone pair of electrons.

Nitrogen has one lone pair of electrons so it can form another bond when Ammonia reacts with Hydrogen ions in an aqueous solution of an acid, an Ammonium ion is formed.

$$NH_{3(g)} + H^+_{(aq)} \longrightarrow NH_4^+{}_{(aq)}$$



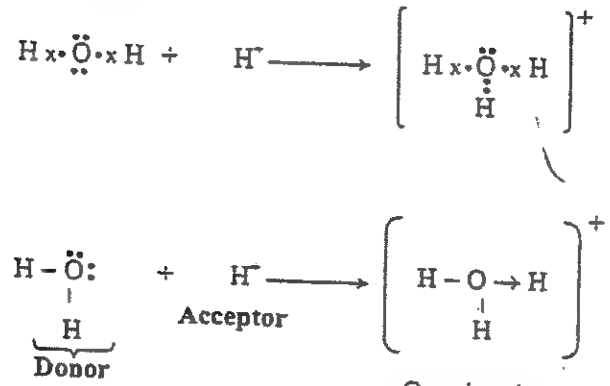
Coordinate covalent bond is indicated by an arrow (→) pointing towards the atom which accepts the electron pair ($NH_3 \rightarrow {}^{+}H$).

## Example# 2:

When an acid dissolves in water, an aqueous solution is formed but a coordinate covalent bond is also formed ...

Oxygen atom in the molecule of water has lone pair of electrons. So, the Hydrogen ions from an acid combines with it. As a result, **Oxonium** ion or **Hydronium** ion ($H_3O^+$) is formed.

$$H_2O + H^+ \longrightarrow H_3O^+$$




Oxonium ion
or
Hydronium ion

Coordinate covalent bond is indicated by an arrow (→) pointing towards the atom which accepts the electron pair ($H_2O \rightarrow {}^{+}H$).



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# EXERCISE

**1. Fill in the blanks:**

(i) ***Non-polar*** Covalent molecule is electrically neutral as well as symmetrical.

(ii) The power of an atom to attract the shared pair of electrons towards itself is called ***Electronegativity.***

(iii) ***Covalent*** compounds are usually made up of discrete units with weak inter-molecular forces.

(iv) NaCl is an ***ionic*** compound.

(v) If electronegativity difference of bonded atoms is more then 1.7, the bond is ***Electrovalent.***

(vi) The electrostatic attraction between positive ions and the electrons of the atoms is called ***Metallic*** Bond.

(vii) The forces which hold atoms together in a molecule are called ***Intra molecular*** forces.

(viii) The attraction between the partially positive Hydrogen and negative F, O or N is called ***Hydrogen*** bonding.

(ix) $CO_2$ is a ***Non-polar*** molecule.

(x) The atom which accepts a lone pair of electrons is called ***Acceptor.***

**2. Tick the correct answer:**

**(i) The force which holds atoms together in a molecule or crystal is called:**
(a) Ionic bond. (b) Covalent bond.
(c) Co-ordinate covalent bond. (d) Chemical bond.

**(ii) The bond which is formed by the transfer of one or more electrons from one atom to another atom is called:**
(a) Ionic bond. (b) Covalent bond.
(c) Co-ordinate covalent bond. (d) Chemical bond.

**(iii) The bond which is formed by mutual sharing of electrons between atoms is called:**
(a) Ionic bond. (b) Covalent bond.
(c) Co-ordinate covalent bond. (d) Chemical bond.

**(iv) The bond which is formed by one-sided sharing of pair of electrons is called:**
(a) Ionic bond. (b) Covalent bond.
(c) Co-ordinate covalent bond. (d) Chemical bond.

**(v) The bond in MgO is:**
(a) Electro-valent bond. (b) Covalent bond.
(c) Co-ordinate covalent bond. (d) Chemical bond.

**(vi) The shared pair of electrons which links the atoms in a molecule is known as:**
(a) Electro-valent bond. (b) Covalent bond.
(c) Co-ordinate covalent bond. (d) Chemical bond.

**(vii) Double covalent bond is denoted by:**

(a) Single short line. (b) Two short lines
(c) Three short lines. (d) none of these

**(viii) The atom which supplies the pair of electrons for bond formation is known as:**

(a) Acceptor. (b) Donor.
(c) Receiver. (d) none of these

**... bond is always formed between two:**

(a) Like atoms. (b) Unlike atoms.
(c) Similar atoms. (d) Like and unlike atoms

**(x) The shared pair of electrons in a co-ordinate covalent bond is denoted by:**

(a) A single line. (b) Double line.
(c) An equal sign (d) Ad arrow.

**Answer:**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| i | d | ii | a | iii | B | iv | c | v | a |
| vi | b | vii | b | viii | B | ix | b | x | d |

## 3. Write answer of the following questions:

**(i) Define chemical bond. Discuss how atoms unite and change into molecules.**

**Ans. Chemical Bond:**

The intra molecular force of attraction, which holds the atoms together in the form of a molecule or holds the ions in the form of crystal, is called a chemical bond.

### Formation of Molecule:

Molecules are formed when the atoms with incomplete outermost shell unite together, for example a Chlorine atom has seven electrons in its outermost shell and requires one more electron to complete its octet. On the other hand, Hydrogen atom has one electron and needs one electron to complete its duplet. Hydrogen and Chlorine both share their electrons to complete their duplet and octet respectively. In this way, a molecule of HCl is formed.


$K^1$ $K^2L^8M^7$

**(ii) What are valence electrons of an atom? How many valence electrons does a Nitrogen atom possess?**

**Ans.** The electrons in the outermost shell of an atom are called valence electrons. As the electronic configuration of Nitrogen is $K^2L^5$, therefore it shows that it has five valence electrons.

**(iii) What happens to electrons when elements combine?**

**Ans.** When elements combine, the valence electrons are either transferred from the outermost shell of one atom to the outermost shell of another atom or shared between them. As a result, a chemical bond is formed.

**(iv) Which part of the atom is involved in the formation of a chemical bond?**

**Ans.** Electrons in the outermost shell are involved in the formation of chemical bond.

(v) **Explain with example. How are elements united by electrovalent bond?**

(Answer on Page # 3 & 4)

(vi) **What common properties are shown by ionic compounds?**

(Answer on Page # 5)

(vii) **What is meant by covalent bond? Write electronic formulae of any two covalent molecules. Explain single, double and triple covalent bonds?**

(Answer on Page # 6)

(viii) **Draw the electronic formulae for the following covalent molecules.**

(a) $H_2$ (b) $O_2$ (c) $N_2$ (d) $C_2H_2$ (e) $CO_2$

Ans. (a)  $H_2$

(b)  $O_2$

(c)  $N_2$

(d)  $C_2H_2$

(e)  $CO_2$



The Covalent bonds formed between non-metal atoms having the difference of electronegativity less then 1.7 are called Polar Covalent bonds.

The Covalent bond formed by the same atoms of a non-metal or different atoms having same electronegativity is called Non-polar covalent bond. In other words, bonds between atoms having the difference of electronegativity less than 0.4 to 0.0 are known as non-polar covalent bonds.

(ix) **Classify the following bonds as ionic or covalent. For those bonds that are covalent, indicate whether they are polar or non-polar.**

(a) $H_2$ (b) H-Cl (c) NaCl (d) $CaCO_3$ (e) HC≡CH (f) O=O

Ans. (a) $H_2$ (Non-polar) (b) H-Cl (Polar) (c) NaCl (Ionic)

(d) $CaCO_3$ (Ionic) (e) HC≡CH (Non-polar) (f) O=O (Non-polar )

(x) **What are the types of chemical bonding?**

Ans. There are two types of chemical bonds. (i) Ionic Bond (ii) Covalent Bond

(xi) **Account for the fact that some covalent bonds are polar while others are non-polar.**

Ans. Covalent bonds are polar and non-polar due to the difference of electronegativity. If the difference of E.N. between covalently bonded atoms is 0.0 to 0.4, then the bond is Non-polar. If the difference of E.N. is above 0.4 to 1.7, then the bond is polar covalent bond.

(xii) **What is co-ordinate covalent bond? Explain with examples.**
**(Answer on Page # 10)**

(xiii) **How does a covalent bond differ from co-ordinate covalent bond?**

| Covalent bond | Co-ordinate Covalent bond |
|---|---|
| mutual sharing of electrons between atoms. | 1. Coordinate covalent bond is formed by one sided sharing of electrons. |
| 2. Covalent bond is formed between similar or dissimilar atoms, when the electrons are mutually shared. | 2. Co-ordinate covalent bond is formed between two unlike atoms, one having an electron pair available for sharing and other for accepting that electron pair. |
| 3. Covalent bond may be Polar or Non-polar | 3. Co-ordinate covalent bond is always Polar, because it is not formed between like atoms and is also known as co-ionic. |
| 4. The shared pairs of electrons in covalent bond are denoted by short lines e.g. (–) for single bond; (=) for double bond and (≡) for triple bond. | 4. The lone pair of electrons in co-ordinate covalent bond is denoted by an arrow (→). |
| 5. Covalent compounds are usually insoluble in water. | 5. Co-ordinate covalent compounds are sparingly soluble in water. |

(xiv) **Explain electronegativity.**

**Ans. Electronegativity:**

The relative tendency of an atom to attract a shared pair of electrons towards itself is called Electronegativity.

**Explanation:**

E.N. values were determined by Linus Pauling. Electronegativity values are based on arbitrary scale in which Fluorine is given an arbitrary standard value of electronegativity as 4.0

Fluorine has the highest E.N. i.e 4.0 and Cesium and Francium have the lowest E.N. value i.e 0.7.

E.N. has no unit.

(xv) **Explain Pauling's (E.N.) table in your own words. Explain its usefulness in predicting the relative ionic and covalent character of a given compound.**

**Ans. Electronegativity (E.N.):**

The relative tendency of an atom to attract a shared pair of electrons is called electronegativity.

## PAULING'S (E.N) TABLE:

Linus Pauling devised a table in which Fluorine is given an arbitrarily E.N. value of 4.0 and the E.N. values of the rest of the elements have been assigned by comparing them with Fluorine.

It is observed that metals have less electronegativities and non metals have greater electronegativities. E.N. values are used to predict the ionic and covalent character of bonds.

## DETERMENATION OF NATURE OF COMPONENTS:

∴ If the difference of E.N. between the bonded atoms is 1.7 or more, the bond is called Ionic bonds.

∴ If the difference of E.N. between the bonded atoms is less then 1.7, the bond is called Covalent bond.

(xvi) **Give the characteristics (properties) of covalent compounds.**

(Answer on Page # 7)

(xvii) **What do you understand by ionic character of covalent bond? Under what conditions are the following formed?**

(a) Polar covalent bond (b) Non-polar covalent bond. (c) Ionic bond.

## Ans. IONIC CHARACTER OF COVALENT BOND:

When a covalent bond is formed between the atoms that have the difference of electronegativity less than 1.7, then the atom with the greater electronegativity attracts the shared pair of electrons. In this way, it has partial negative charge ($\delta^-$) and the atom with the lesser E.N. value has partial positive charge ($\delta^+$). These partial charges are considered as ionic character of covalent bond.

**(a) Polar covalent bond:** (Answer on Page # 7)

**(b) Non-polar covalent bond:** (Answer on Page # 7)

**(c) Ionic bond:** (Answer on Page # 4)

(xviii) **Define the term metal. Describe metallic bond.**

### Ans. Metal:

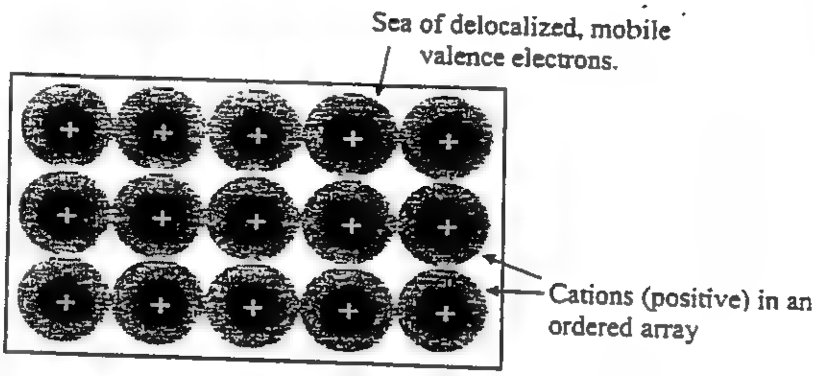
A substance consisting of positively charged ions, fixed in a crystal lattice with negatively charged electrons moving freely through the crystal.

### Metallic Bond:

The electrostatic force of attraction between positively charged nuclei and freely moving electrons (mobile electrons) is called metallic bond.

## Explanation:

Metals have less than four valence electrons and many metals have only one or two electrons. These electrons, instead of remaining in a particular atom, move freely from one atom to another atom. Hence, the atoms are considered to be positively charged ions. due to this reason a force of attraction develops between mobile [illegible] and positively charged ions, which is called Metallic Bond. In this way, freely moving electrons act as cohesive force, which hold the atoms together.




(xix) **Explain the following properties of metals?**

(a) Lustre (b) Conductivity (c) Malleability (d) Ductility

a) **Lustre:**

Metals have shiny surface.

b) **Conductivity:**

Metals are very good conductors of heat and electricity because of the presence of freely moving electrons. These electrons carry electrical charge.

c) **Malleability:**

Metals have strong metallic bond due to which the layers of atoms slip over another and change their position when hammered due to which the metal spreads into sheets.

d) **Ductility:**

Due to strong bonding between the atoms, when a piece of metal is stretched, atoms adjust themselves in longitudinal direction. In this way, they can be converted into wires. Therefore metals are ductile.

(xx) **Why are some metals, such as Sodium soft, while others are hard?**

**Ans.** Sodium has relatively weak metallic bonds. As it has less number of free electrons. therefore a weak cohesive force exists between atoms. Due to this. it is a soft metal while metals having greater number of mobile electrons are hard due to the formation of more metallic bonds between these mobile electrons and nuclei.

**(xxi) Explain the origin of dipole-dipole forces? Give an example.**

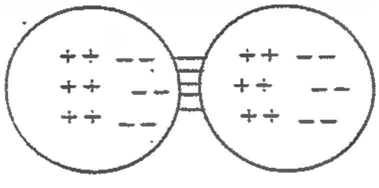
Ans. The origin of Dipole – Dipole Interaction is the polarity of molecules due to the difference of electronegativity. It is the force of attraction between partial positive end of a molecule and partial negative end of its neighbouring molecule.

Example: (HCl Molecule) (Answer on Page # 7)

**(xxii) What do you mean by dispersion forces? Why are they are also called London forces?**

## Ans. DISPERSION FORCE OR LONDON FORCE:

The force of attraction between temporarily polarized atoms due to the change of position of electron by induction is called Dispersion Force or London Force.



Note: The London Force is given after the name of its discoverer **Fritz London**.

**(xxiii) What is Hydrogen bonding? What type of forces, either intra-molecular or inter-molecular forces are present in Hydrogen bonding?**

**Ans. HYDROGEN BOND:** (Answer on Page # 9 and 10)

**(xxiv) Define the following.**

i) **Inter molecular force of attraction.**
ii) **Intra molecular force of attraction.**

## INTER MOLECULAR FORCE OF ATTRACTION:

***The force of attraction between the molecules of compounds is called inter molecular force of attraction.***

**Example:**

i) Dipole-Dipole attraction
ii) Hydrogen bond
iii) Metallic bond
iv) London force

## INTRA MOLECULAR FORCE OF ATTRACTION:

***The force of attraction which holds the unstable atoms in a molecule or crystal is called intra molecular force of attraction.***

**Example:**

i) Ionic bond.
ii) Covalent bond.

SESSION
2016-2017



# CLASS-XI

# CHEMISTRY

## Chapter # 6

## CHEMICAL EQUILIBRIUM

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# CHEMICAL EQUILIBRIUM 6

There are two types of chemical reactions
(i) Reversible (ii) Irreversible

## Reversible Reactions:

*"Those chemical reactions which take place in both the directions and never proceed to completion are called reversible reactions."*

For these type of reactions, both the forward and the reverse reactions occur at the same time, so these reactions are generally represented as

$$\text{Reactants} \rightleftharpoons \text{Products}$$

The double arrow indicates that the reaction is reversible, and both the forward and the reverse reaction occur simultaneously. In other words we can say that, reactions in which reactants and products both are interconvertible, are called reversible reactions.

Some examples of reversible reactions are given below

(i) $N_2 + 3H_2 \rightleftharpoons 2NH_3$

(ii) $2SO_2 + O_2 \rightleftharpoons 2SO_3$

## Irreversible Reactions:

"Those reactions in which reactants are converted into product only are called irreversible reactions"

These reactions proceed only in forward direction.

Reactions in which reactants are converted into products but products are not converted back into reactants are called irreversible reactions.

Examples of such type of reactions are given below

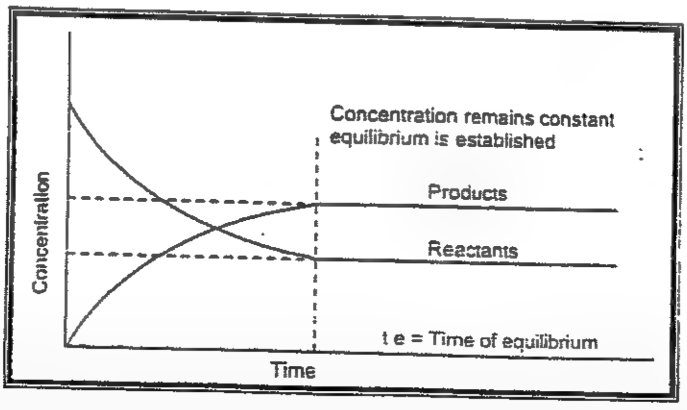
$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

$$NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$$

## Equilibrium State:

The state at which the rate of forward reaction becomes equal to the rate of reverse reaction is called Equilibrium state or chemical equilibrium. This type of equilibrium is also called ***Dynamic equilibrium.***

The state that is reached when the concentration of reactants and products becomes constant with respect to time is called the state of chemical equilibrium. A mixture of reactants and products in the equilibrium state is called ***equilibrium mixture.***



## Explanation:

Consider the following reaction

$$A + B \rightleftharpoons C + D$$

It is a reversible reaction. In this reaction, both the reactions (i.e. forward & backward) occur simultaneously. At initial state, reactants A and B are present in a reaction vessel and the concentration of C and D is zero.

As when the reaction proceeds and the molecules of A & B react with each other, the concentration of reactants is decreased, while the concentration of products is increased. With the formation of the products, the reverse reaction starts. As the time goes on, the rate of forward reaction decreases because the concentration of reactant decreases, and it is converted into product, on the other hand the rate of reverse reaction increases because of the increase in the concentration of products C and D. Ultimately, a state reaches when both the reaction rates, forward and backward becomes equal. This state is called Equilibrium state.

## Active Mass or Molar Concentration:

*Number of moles of any substance in one $dm^3$ of solution is called Active mass or Molar concentration.*

$$\text{Active mass} = \frac{\text{Number of moles}}{\text{Volume of solution in } dm^3}$$

## LAW OF MASS ACTION:

### Introduction:

The effect of concentration on reversible reaction at equilibrium was explained by Scandinavian scientists Guldberg and Waage in 1864. Their observation is known as the law of mass action (or) law of equilibrium.

### Statement:

*"The rate at which a substance reacts is directly proportional to its active mass, and the rate of a chemical reaction is directly proportional to the product of the active masses of the reactants"*

### Derivation of Equilibrium Constant:

Consider a reversible reaction, in which 'm' moles of A and 'n' moles of B react to give 'x' moles of C and 'y' moles of D as shown in the equation

$$mA + nB \rightleftharpoons xC + yD$$

A to law of mass of action

The rate of forward reaction $\propto [A]^m [B]^n$

The rate of forward reaction $= K_f [A]^m [B]^n$

The rate of reverse reaction $\propto [C]^x [D]^y$

The rate of reverse reaction $= K_r [C]^x [D]^y$

At equilibrium state

Rate of forward reaction = Rate of reverse reaction

Therefore $K_f [A]^m [B]^n = K_r [C]^x [D]^y$

$$\frac{K_f}{K_r} = \frac{[C]^x [D]^y}{[A]^m [B]^n}$$

$$K_c = \frac{[C]^x [D]^y}{[A]^m [B]^n}$$

$$K_c = \frac{[\text{product}]}{[\text{reactant}]}$$



The above expression is called equilibrium expression. Where $K_C$ is Equilibrium constant with respect to concentration, which is defined as;

The ratio between multiplications of active masses of the products to the multiplication of active masses of reactants at equilibrium state is called equilibrium constant.

## Units of Equilibrium Constants

If the reaction has equal number of moles on the reactant and product side, then equilibrium constant has no units. When the number of moles is unequal than it has units related to the concentration (or) pressure But it is a usual practice that we don't write the units with $K_c$ or or $K_p$ values e.g

(i) $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$.

$$K_c = \frac{[CH_3COOC_2H_5][H_2O]}{[CH_3COOH][C_2H_5OH]} = \frac{[\text{moles dm}^{-3}][\text{moles dm}^{-3}]}{[\text{moles dm}^{-3}][\text{moles dm}^{-3}]} = \text{No unit}$$

(ii) $N_2 + 3H_2 \rightleftharpoons 2NH_3$

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{[\text{moles dm}^{-3}]^2}{[\text{moles dm}^{-3}][\text{moles dm}^{-3}]^3} = \text{moles}^{-2}\,\text{dm}^{-6}$$

(iii) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{[\text{moles dm}^{-3}][\text{mole dm}^{-3}]}{[\text{moles dm}^{-3}]} = \text{moles dm}^{-3}$$



## Equilibrium Constant for a Gaseous System:

Consider a reversible process in which the reactants and products are gases as shown:

$$A_{(g)} + B_{(g)} \rightleftharpoons C_{(g)} + D_{(g)}$$

When the reactants and products are in gaseous state, their partial pressures are used instead of their concentrations, so according to Law of mass action:

$$K_p = \frac{(P_C)\ (P_D)}{(P_A)\ (P_B)}$$

Where $P_A$, $P_B$, $P_C$ and $P_D$ are the partial pressures of reactants and products.

## Relationship between $K_C$ and $K_P$:

There are three possibilities in the relationship between $K_C$ and $K_P$ which are as follows:

(i) $K_P = K_C$

In a chemical reaction if there is no change in number of moles before and after the reaction then $K_C = K_P$

**Example:** $H_2 + I_2 \rightleftharpoons 2HI$

In other words we can say that reactions in which number of moles of products and reactants are same, then $K_C = K_P$

(ii) $K_P > K_C$

When reaction occur with increase in number of mole such as

$$2NH_3 \rightleftharpoons N_2 + 3H_2$$

For such reaction $K_P > K_C$

It means that when number of moles of product are greater than number of moles of reactants then $K_P > K_C$

(iii) $K_P < K_C$

Reactions in which number of moles of products are less than number of moles of reactant then $K_P < K_C$ or when there is decrease in number of mole on the product side e.g.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

In this case $K_P < K_C$

There are two important applications of equilibrium constant.

(i) It is used to predict the direction of reaction.

(ii) $K_C$ is also used to predict the extent of reaction.

## To Predict the Direction of Reaction:

The value of equilibrium constant $K_C$ is used to predict the direction of a reversible reaction

$$\text{Reactant} \rightleftharpoons \text{Product}$$

With respect to the ratio of initial concentration of the product and reactant there are three possibilities

$$\text{Let} \frac{[\text{Product}]_{\text{initial}}}{[\text{reactant}]_{\text{initial}}} = K_{\text{initial}}$$

There are three possibilities for $K_{initial}$

(i) It is greater than $K_C$ (ii) It is less than $K_C$

(iii) It is equal to $K_C$

**CASE I:**

$$\text{If } \frac{[\text{Product}]_{\text{initial}}}{[\text{Reactant}]_{\text{initial}}} > K_C$$

The reaction will shift towards the reverse direction.

**CASE II:**

$$\text{If } \frac{[\text{Product}]_{\text{initial}}}{[\text{Reactant}]_{\text{initial}}} < K_C$$

The reaction will shift towards the forward direction.

**CASE III:**

$$\text{If } \frac{[\text{Product}]_{\text{initial}}}{[\text{Reactant}]_{\text{initial}}} = K_C$$

The reaction is already at equilibrium state.

## To Predict the Extent of Reaction:

From the value of $K_C$ we can predict the extent of the reaction.

(1) If the value of $K_C$ is very large e.g.

For $2O_3 \rightleftharpoons 3O_2$ $K_C = 1 \times 10^{55}$ (very large value)

From this large value of $K_C$, it is predicted that the forward reaction is almost complete i.e reactant is unstable, product is stable and reaction is almost complete in forward direction.

(2) When the value of $K_C$ is very low e.g.



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$$2HF \rightleftharpoons H_2 + F_2 \qquad K_C = 1 \times 10^{-13} \qquad \text{(very small value)}$$

From this value it is predicted that the forward reaction proceeds with negligible rate. i.e reactant is stable , product is unstable and reaction is almost complete in reverse direction.

(3) If the value of $K_C$ is moderate, the reaction occurs in both the direction and equilibrium will be established after certain period of time

So the reaction occurs in both the directions, i.e both reactant and product are unstable and interconvertible to each other.

## Determination of Equilibrium Constant:

The value of equilibrium constant $K_C$ does not depend upon the initial concentration of reactants. In order to find out the value of $K_C$, we have to find out the equilibrium concentration of reactants and products.

## Ethyl Acetate Equilibrium:

- Acetic acid reacts with ethyl alcohol to form ethyl acetate and water as shown in the following equation.

$$\underset{\text{Acetic Acid}}{CH_3COOH} + \underset{\text{Ethyl Alcohol}}{C_2H_5OH} \rightleftharpoons \underset{\text{Ethyl Acetate}}{CH_3COOC_2H_5} + \underset{\text{Water}}{H_2O}$$

Suppose 'a' moles of Acetic acid and 'b' moles of Ethyl alcohol are mixed in a reaction vessel. After some time when the state of equilibrium is established suppose 'x' moles of $H_2O$ and x moles of Ethyl acetate are formed while the number of moles of Acetic acid and alcohol are a-x and b-x respectively at equilibrium, so we can write as:

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

| | | | | |
|---|---|---|---|---|
| Initial moles | a | b | zero | zero |
| Moles at equiliburm | $(a-x)$ | $(b-x)$ | x | x |
| Concentration at equilibrium | $\left(\frac{a-x}{v}\right)$ | $\left(\frac{b-x}{v}\right)$ | $\left(\frac{x}{v}\right)$ | $\left(\frac{x}{v}\right)$ |

According to law of mass action

$$K_c = \frac{[CH_3COOC_2H_5]\,[H_2O]}{[CH_3COOH]\,[C_2H_5OH]}$$

$$K_c = \frac{[x/v][x/v]}{[a-x/v][b-x/v]} = \frac{(x)\,(x)}{(a-x)\,(b-x)}$$

$$K_c = \frac{x^2}{(a-x)\,(b-x)}$$

## Hydrogen Iodide Equilibrium:

For the reaction between Hydrogen and Iodine, suppose 'a' moles of Hydrogen and 'b' moles of Iodine are mixed in a sealed bulb at 444°C in boiling Sulphur for some time. The equilibrium mixture is then cooled and the bulb is opened in a solution of NaOH. Let the amount of Hydrogen consumed at equilibrium be 'x' moles, which means that the amount of Hydrogen left at equilibrium is 'a-x' moles.

Since '1' mole of $H_2$ reacts with '1' mole of $I_2$ to form two moles of HI, hence the amount of Iodine used is also 'x' moles so its moles at equilibrium is b-x and the moles of Hydrogen iodide at equilibrium are 2x so we can write as:

$$H_2 + I_2 \rightleftharpoons 2HI$$

| | $H_2$ | $I_2$ | $2HI$ |
|---|---|---|---|
| Initial moles | a | b | zero |
| Moles at equilibrium | $(a-x)$ | $(b-x)$ | $2x$ |
| Concentration at equilibrium | $\left[\frac{a-x}{v}\right]$ | $\left[\frac{b-x}{v}\right]$ | $\left[\frac{2x}{v}\right]$ |

According to the law of mass action,

$$K_c = \frac{[HI]^2}{[H_2][I_2]} = \frac{\left[\frac{2x}{v}\right]^2}{\left[\frac{a-x}{v}\right]\left[\frac{b-x}{v}\right]}$$

$$K_c = \frac{4x^2}{(a-x)(b-x)}$$



## LE-CHATELIER'S PRINCIPLE:

**Statement:** *"When a stress is applied to a reversible reaction at equilibrium, the equilibrium position changes so as to minimize the effect of applied stress".*

The equilibrium state of a chemical reaction is altered by changing concentration, pressure or temperature. The effect of these changes is explained by Le-Chatelier

### Effect of Concentration:

By changing the concentration of any substance present in the equilibrium mixture, the balance of chemical equilibrium is disturbed. For the reaction

$$A + B \rightleftharpoons C + D$$

$$K_c = \frac{[C][D]}{[A][B]}$$

If the concentration of reactant A or B is increased the equilibrium state shifts towards right and yield of products increases.

But if the concentration of C or D is increased, then the reaction proceed in the backward direction with a greater rate and more A & B are formed, so as to re-establish the equilibrium.

### Effect of Temperature:

The effect of temperature depends upon the type of reaction.

For an exothermic reaction, the value of $K_C$ decreases with the increase of temperature so the concentration of products decreases.

For an endothermic reaction heat is absorbed for the conversion of reactants into product, so if temperature during the reaction is increased, then the reaction will proceed with a greater rate in forward direction

**Endothermic Reaction**
- **Temperature increase** → More products are formed i.e. reaction proceeds in forward direction
- **Temperature decrease** → More reactants are formed i.e. reaction proceeds in backward direction

**Exothermic Reaction**
- **Temperature increase** → More reactants are formed i.e. reaction proceeds in backward direction
- **Temperature decrease** → More products are formed i.e. reaction proceeds in forward direction

## Effect of Pressure:

The state of equilibrium of gaseous reaction is disturbed by the change of pressure. By *increasing* pressure the equilibrium will shift in that direction where volume (moles) decreases.

By *decreasing* pressure the Equilibrium will shift in that direction where volume (moles) increases.

There are three types of reactions, which show the effect of pressure change.

## When the Number of Moles of Products are Greater:

In a reaction such as

$$2NH_3 \rightleftharpoons N_2 + 3H_2$$

The increase of pressure shifts the equilibrium towards reactant side and decrease in pressure shifts equilibrium in forward direction.

## When the Number of Moles of Reactants are Greater:

In a reaction such as

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

The increase of pressure shifts the equilibrium towards product side because the numbers of moles of product are less than the number of moles of reactants and decrease in pressure shifts equilibrium in backward direction.

## When Number of Moles of Reactants and Product are Equal:

In those reactions where the number of moles of reactants are equal to the number of moles of products the change of pressure does not change the equilibrium state e.g.

$$\underset{1\text{mole}}{H_2} + \underset{1\text{mole}}{I_2} \rightleftharpoons \underset{2\text{mole}}{2HI}$$

Since the number of moles of reactants and product are equal in this reaction so the increase of pressure does not affect the yield of HI.

## Effect of Catalyst:

Catalyst has no effect on state of equilibrium it only reduces, or increases the time to reach equilibrium.

## Important Industrial Applications of Le-Chatelier's Principle:

### HABER'S PROCESS:

Synthesis of ammonia by Haber process is an reversible exothermic reaction. In this process one volume of Nitrogen is mixed with three volumes of Hydrogen at 500°C and 200 to 1000atm pressure in the presence of a catalyst

$$N_2 + 3H_2 \underset{\text{Catalyst}}{\rightleftharpoons} 2NH_3 + \text{Heat}$$

### Effect of Concentration:



$K_C$ for this reaction is

$$K_C = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

Increase in concentration of reactants, which are $N_2$ and $H_2$, the equilibrium of the process shifts towards the right so as to keep the value of $K_C$ constant. Hence the formation of $NH_3$ increases with the increase of the concentration of $N_2$ or $H_2$.

### Effect of Temperature:

It is an exothermic process, so heat is liberated with the formation of product. Therefore according to Le-Chatelier's principle at low temperature, the equilibrium is shifted towards right to balance the equilibrium state so low temperature favours the formation of $NH_3$.

### Effect of Pressure:

The formation of $NH_3$ proceeds with the decrease in volume, therefore reaction is carried out under high pressure or in other words high pressure is favorable for the production of $NH_3$.

### CONTACT PROCESS:

This process is used to manufacture $H_2SO_4$ on large scale. In this process the most important step is the oxidation of $SO_2$ to $SO_3$ in the presence of a catalyst Vandium pentoxide

$$2SO_2 + O_2 \underset{V_2O_5}{\rightleftharpoons} 2SO_3 + \text{Heat}$$

### Effect of Concentration:

The value of $K_C$ for this reaction

$$K_C = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

Increase in concentration of $SO_2$ or $O_2$ shift the equilibrium towards right and more $SO_3$ is formed.

### Effect of Temperature:

Since the reaction is exothermic, so low temperature will favour the formation of $SO_3$. The optimum temperature for this reaction is 400 to 450°C

### Effect of Pressure:

In this reaction decrease in volume takes place, so high pressure is favorable for the formation of $SO_3$.

## COMMON ION EFFECT:

"The process in which precipitation of an electrolyte is caused by lowering the degree of ionization of a weak electrolyte, when a common ion is added, is known as common ion effect."

### Explanation:

In the solution of an electrolyte in water, there exist an equilibrium between the ... law of mass action can be applied.

Consider the dissociation of an electrolyte AB. If now another electrolyte yielding $A^+$ or $B^{-1}$ ions be added to the above solution, it will result in the increase of concentration AB. In other words "the degree of dissociation of an electrolyte is suppressed by the addition of another electrolyte containing a common ion." This phenomenon is known as common ion effect.

### Application of common ion effect in salt analysis:

An electrolyte is precipitated from its solution only when the product of concentration of its ions exceed from its solubility product. The precipitates are obtained when the concentration of any one ion is increased. Thus by adding a common ion, the Ionic product can be exceeded. Common ion effect has a great application in qualitative salt analysis. The cations of group II and IV are precipitated as sulphide with $H_2S$, but the cations of group II required less concentration of $S^{-2}$ for precipitation as compared to group IV, so before adding $H_2S$ in the salt solution, we add dilute HCl. HCl gives $H^+$ ion which is common to $H^+$ ion of $H_2S$ which shift the equilibrium of $H_2S$ towards backward, hence the concentration of $S^{-2}$ decreases which is enough to precipitate the cations of group II, not the cations of group IV.

## SOLUBILITY:

*The amount of solute required to prepare a saturated solution of unit volume at specific temperature is called solubility.*

### Solubility Product:

*"The product of the concentration of ions in the saturated solution of a sparingly soluble salt is called solubility product."*

When a slightly soluble ionic solid such as silver chloride is dissolved in water, it dissociate into its ions

These $Ag^+$ and $Cl^-$ ions from solid phase pass into solution till the solution becomes saturated. Now there exists an equilibrium between the ions present in the saturated solution and that in the solid phase, thus

Applying the law of mass action

Since the concentration of solid AgCl in the solid phase is fixed, no matter how much solid is present in contact with solution, so we can write

$$AgCl \rightleftharpoons Ag^+ + Cl^-$$

$$K_c = \frac{[Ag^+][Cl^-]}{[AgCl]}$$

$$K_c[AgCl] = [Ag^+][Cl^-]$$

$$K_{s.p.} = [Ag^+][Cl^-]$$

Where $K_{sp}$ is known as solubility product

The value of solubility product is constant for a given temperature.

The mass of a solute present in a saturated solution with a fixed volume of solvent is called solubility, which is generally represented in the unit of $gm/dm^3$, with the help of solubility we can calculate the solubility product of a substance

## Application of solubility product:

The solubility product $K_{S.P}$ is used to determine weather precipitate should form from a solution of known ionic concentration or not

For a saturated solution the product of ionic concentration is equal to the solubility product but if the ionic product is less than the solubility product, the solution is not saturated therefore more amount of the solute can be dissolved into the solution. On the other hand if the ionic product is greater than the solubility product, the solution is said to be super saturated and the excess of solute should precipitate to restore the equilibrium condition.

## NUMERICALS:

### Solubility Product:

The product of concentration of ions present in a saturated solution of partially soluble salt is called Solubility Product.

### Calculation of Solubility Product from Solubility:

In a saturated solution of AgCl, the solubility of AgCl at 25°C is $1.4 \times 10^{-3}$ $g/dm^3$

To calculate Solubility Product first of all we will calculate the concentration of the solution.

Conc. of AgCl = $Moles/dm^3$

$$Moles/dm^3 \text{ of AgCl} = \frac{1.4 \times 10^{-3}}{143.5} = 0.98 \times 10^{-5}\ mole/dm^3$$

$\therefore$ the Conc. of AgCl $= 0.98 \times 10^{-5}\ mole/dm^3$

In a saturated solution of AgCl

$$AgCl \rightleftharpoons Ag^+ + Cl^-$$

$$\therefore K_{S.P} = [Ag^+][Cl^-]$$



Since the Conc. of AgCl $= 0.98 \times 10^{-5}\ mole/dm^3$

From the above equation it is very clear that 1 mole of AgCl on complete dissolution give 1mole of $Ag^+$ ions and 1mole of $Cl^-$ ions.

$\therefore$ the Conc. of $Ag^+ = 0.98 \times 10^{-5}\ mole/dm^3$

Similarly the Conc. of $Cl^- = 0.98 \times 10^{-5}\ mole/dm^3$

So $K_{S.P} = [0.98 \times 10^{-5}][0.98 \times 10^{-5}]$

$\boxed{K_{S.P} = 0.96 \times 10^{-10}\ mole^2/dm^6}$ Ans.

Q. The solubility of $Mg(OH)_2$ at 25°C is 0.00764 $g/dm^3$. What is the solubility product of $Mg(OH)_2$

Solution:

Molecular Mass of $Mg(OH)_2 = 58$

$$Mg(OH)_2 \rightleftharpoons Mg^{+2} + 2OH^-$$

$$K_{S.P} = [Mg^{+2}]\,[OH^-]^2$$

$$\text{Conc. of } Mg(OH)_2 = \frac{0.00764}{58} = 1.31 \times 10^{-4} \text{ mole/dm}^3$$

$\therefore$ the Conc. of $Mg^{+2} = 1.31 \times 10^{-4}$ mole/dm$^3$

and Conc. of $OH^- = 2.62 \times 10^{-4}$ mole/dm$^3$

$$K_{S.P} = [Mg^{+2}]\,[OH^-]^2$$
$$= [1.31 \times 10^{-4}]\,[2.62 \times 10^{-4}]^2$$
$$= 9.0 \times 10^{-12} \text{ mole}^3/\text{dm}^9$$

## Calculation of Solubility from Solubility Product:

Solubility Product of $PbI_2 = 1.00 \times 10^{-9}$ mole$^3$/dm$^9$

T = 25°C

Solubility of $PbI_2$ = ?

$$PbI_2 \rightleftharpoons Pb^{+2} + 2I^-$$

$$K_{S.P} = [Pb^{+2}]\,[I^-]^2$$

Let the Conc. of $PbI_2 = x$

$\therefore$ the Conc. of $Pb^{+2} = x$

and the Conc. of $I^- = 2x$

substitute the values

$$1.00 \times 10^{-9} = [x]\,[2x]^2$$
$$1.00 \times 10^{-9} = x\,(4x^2)$$
$$4x^3 = 1.00 \times 10^{-9}$$
$$x^3 = 0.25 \times 10^{-9}$$
$$\text{or} \quad x = 0.63 \times 10^{-3}$$

$\therefore$ the Conc. of $PbI_2 = 0.63 \times 10^{-3}$ mole/dm$^3$

To Calculate the mass of $PbI_2$

$$\text{Mole} = \frac{\text{Mass}}{\text{Mol.Mass}}$$

$$0.63 \times 10^{-3} = \frac{\text{Mass}}{461}$$

$$\text{Mass} = 0.63 \times 10^{-3} \times 461 = 0.29 \text{ gm}$$

Solubility of $PbI_2 = 0.29$ g/dm$^3$



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**Q.** **What is the solubility of $PbCrO_4$ in moles/dm$^3$ at 25°C. $K_{S.P}$ for $PbCrO_4 = 2.8 \times 10^{-13}$ mole$^2$/dm$^6$.**

**Solution:**

$K_{S.P}$ of $PbCrO_4 = 2.8 \times 10^{-13}$ mole$^2$/dm$^6$

T = 25°C

Solubility of $PbCrO_4$ = ?

$$PbCrO_4 \rightleftharpoons Pb^{+2} + CrO_4^{-2}$$

$$K_{S.P} = [Pb^{+2}][CrO_4^{-2}]$$

Let the concentration of $Pb^{+2}$ = x

The concentration of $CrO_4^{-2}$ = x



$2.8 \times 10^{-13} = [x][x] \quad \therefore x^2 = 2.8 \times 10^{-13}$

$x = 0.529 \times 10^{-7}$ mole/dm$^3$

Solve The Conc. of $PbCrO_4$ = $0.529 \times 10^{-7}$ mole/dm$^3$

From the given equation it is clear that 1mole of $Pb^{+2}$ ions are formed from 1mole of $PbCrO_4$

$\therefore$ Solubility of $PbCrO_4$ is $0.529 \times 10^{-7}$ mole/dm$^3$

## Application of Solubility Product:

**Q. Should $PbCrO_4$ precipitate from a solution prepared by mixing 100cm$^3$ of $2.5 \times 10^{-4}$M $Pb(NO_3)_2$ and 300 cm$^3$ of $1.5 \times 10^{-8}$M $K_2CrO_4$?**

**$K_{S.P}$ of $PbCrO_4$ = $1.5 \times 10^{-14}$ mole$^2$/dm$^6$.**

<u>Solution:</u>



Conc. of $Pb(NO_3)_2$ = $2.5 \times 10^{-4}$M

Vol. of $Pb(NO_3)_2$ = 100 cm$^3$

Conc. of $K_2CrO_4$ = $1.5 \times 10^{-8}$M

Vol. of $K_2CrO_4$ = 300 cm$^3$

$K_{S.P}$ of $PbCrO_4$ = $1.5 \times 10^{-14}$ mole$^2$/dm$^3$

Conc. of $Pb^{+2}$ after mixing the solutions = $\frac{100}{400} \times 2.5\times10^{-4} = 0.625\times10^{-4}$ M

Conc. of $CrO_4^{-2}$ after mixing the solutions = $\frac{300}{400} \times 1.5\times10^{-8} = 1.125\times10^{-8}$ M

Ionic product = $[Pb^{+2}][CrO_4^{-2}]$

Ionic product = $[0.625 \times 10^{-4}][1.125 \times 10^{-8}]$

$= 7.03 \times 10^{-13}$

Since the ionic product of $Pb^{+2}$ and $CrO_4^{-2}$ is greater than solubility product, hence $PbCrO_4$ should precipitate out from the solution.

**Q. Should AgCl precipitate from a solution prepared by mixing 400ml of 0.1M NaCl and 600 ml of 0.03 M $AgNO_3$ $K_{S.P}$ of AgCl = $1.6 \times 10^{-10}$ mole$^2$/dm$^3$**

<u>Solution:</u>

Conc. of NaCl = 0.1 M

Vol. of NaCl = 400ml

Conc. of $AgNO_3$ = 0.03 M

Vol. of $AgNO_3$ = 600ml

$K_{S.P}$ of AgCl $= 1.6 \times 10^{-10}$ $mole^2/dm^6$

Conc. of $Ag^+$ after mixing $= \dfrac{600}{1000} \times 0.03 = 0.018\,M$

Conc. of $Cl^-$ after mixing $= \dfrac{400}{1000} \times 0.1 = 0.04\,M$

Ionic product $= [Ag^+][Cl^-]$

$= 7.2 \times 10^{-4}$ $mole^2/dm^6$

The Ionic product is greater than solubility product therefore precipitates should be formed.

## NUMERICALS FROM PROGRESS TEST:

**Q. A quantity of $PCl_5$ was heated in a 12 $dm^3$ vessel at 250°C**

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

**At equilibrium the vessel contains 0.21 moles $PCl_5$, 0.32 mole $PCl_3$ and 0.32 mole $Cl_2$. Compute the equilibrium constant $K_C$.**

Given Data:

$PCl_5$ at $eq^m$ = 0.21 mole

$PCl_3$ at $eq^m$ = 0.32 mole

$Cl_2$ at $eq^m$ = 0.32 mole

Volume of vessel = 12 $dm^3$



Conc. of reactant and products at equilibrium

$$[PCl_5]=\left[\frac{0.21}{12}\right]$$

$$[PCl_3]=\left[\frac{0.32}{12}\right]$$

$$[Cl_2]=\left[\frac{0.32}{12}\right]$$

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Equilibrium constant for the reaction

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]}$$

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Substitute these values

$$K_c = \frac{\left[\frac{0.32}{12}\right]\left[\frac{0.32}{\cancel{12}}\right]}{\left[\frac{0.21}{\cancel{12}}\right]} = \frac{0.32 \times 0.32}{12 \times 0.21} = 0.040$$

$$\text{Unit of } K_c = \frac{\frac{mole}{dm^3} \times \frac{mole}{dm^3}}{\frac{mole}{dm^3}}$$

$$\frac{mole}{dm}$$



$$\therefore \quad \boxed{Kc = 0.040 \frac{mole}{dm^3}} \quad \text{Ans.}$$

**Q. One mole of HI is introduced into a vessel held at constant temperature. When equilibrium is reached it is found that 0.1 mole of $I_2$ have been formed. Calculate the equilibrium constant, $K_C$.**

<u>Given Data:</u>

Initial mole of HI = 1 mole
Moles of $I_2$ at eq$^m$ = 0.1 mole
$K_C$ = ?

$$2HI \rightleftharpoons H_2 + I_2$$

| | $2HI$ | $H_2$ | $I_2$ |
|---|---|---|---|
| Initial moles | 1 mole | zero | zero |
| Moles at eq$^m$ | 1-2(0.1) | 0.1 | 0.1 |
| Moles at eq$^m$ | 1-0.2 | 0.1 | 0.1 |
| Conc. at eq$^m$ | $\left[\frac{0.8}{v}\right]$ | $\left[\frac{0.1}{v}\right]$ | $\left[\frac{0.1}{v}\right]$ |

$$K_c = \frac{[H_2][I_2]}{[HI]^2} = \frac{\left[\frac{0.1}{\cancel{v}}\right]\left[\frac{0.1}{\cancel{v}}\right]}{\left[\frac{0.8}{\cancel{v}}\right]^2}$$

$$= \frac{0.1 \times 0.1}{0.64} = 0.0156$$

$$\text{Unit of } K_c = \frac{[H_2][I_2]}{[HI]^2}$$

$$= \frac{\frac{mole}{v} \times \frac{mole}{v}}{\left(\frac{mole}{v}\right)^2} = 1$$



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$\boxed{K_c = 0.0156}$ **Ans.**

**Q. When 1 mole of pure Ethyl alcohol is mixed with 1 mole of Acetic acid, the equilibrium mixture contain 2/3 mole each of ester and $H_2O$. What is the equilibrium constant?**

$$C_2H_5OH + CH_3COOH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

| | $C_2H_5OH$ | $CH_3COOH$ | $CH_3COOC_2H_5$ | $H_2O$ |
|---|---|---|---|---|
| Initial moles | 1 mole | 1 mole | zero | zero |
| Moles at eq$^m$ | $1-\frac{2}{3}$ | $1-\frac{2}{3}$ | $\frac{2}{3}$ | $\frac{2}{3}$ |
| | $\left[\frac{1/3}{v}\right]$ | $\left[\frac{1/3}{v}\right]$ | $\left[\frac{2/3}{v}\right]$ | $\left[\frac{2/3}{v}\right]$ |

Conc. at eq$^m$

$$\therefore K_c = \frac{[CH_3COOC_2H_5][H_2O]}{[C_2H_5OH][CH_3COOH]}$$

$$K_c = \frac{\left[\frac{2/\cancel{3}}{\cancel{v}}\right]\left[\frac{2/\cancel{3}}{\cancel{v}}\right]}{\left[1/\cancel{3}\right]\left[1/\cancel{3}\right]} = \frac{2 \times 2}{1} = 4$$

$$\text{Unit of } K_c = \frac{\frac{mole}{v} \times \frac{mole}{v}}{\frac{mole}{v} \times \frac{mole}{v}} = 1$$

$\boxed{\therefore Kc = 4}$ **Ans.**

**Q. How many moles of ester are formed at equilibrium when 3 moles of alcohol are mixed with 1 mole of acid.**

**Solution:**

Initial moles of $C_2H_5OH$ = 3 moles
Initial moles of $CH_3COOH$ = 1 mole
$K_C$ = 4
Moles of $CH_3COOC_2H_5$ (ester) = ?

| | $C_2H_5OH$ + | $CH_3COOH \rightleftharpoons$ | $CH_3COOC_2H_5$ + | $H_2O$ |
|---|---|---|---|---|
| Initial moles | 3 moles | 1 mole | zero | zero |
| Moles at eq$^m$ | (3-x) moles | (1-x) mole | x | x |
| Conc. at eq$^m$ | $\left[\frac{3-x}{v}\right]$ | $\left[\frac{1-x}{v}\right]$ | $\left[\frac{x}{v}\right]$ | $\left[\frac{x}{v}\right]$ |

$$K_c = \frac{\left[\frac{x}{\cancel{v}}\right]\left[\frac{x}{\cancel{v}}\right]}{\left[\frac{3-x}{\cancel{v}}\right]\left[\frac{1-x}{\cancel{v}}\right]}$$

$$4 = \frac{x^2}{(3-x)(1-x)}$$

$$4(3-x)(1-x) = x^2$$
$$4(3-3x-x+x^2) = x^2$$
$$4(3-4x+x^2) = x^2$$
$$12-16x+4x^2 = x^2$$
$$3x^2-16x+12 = 0$$

a = 3, b = -16, c = 12

$$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$$

$$x = \frac{-(-16) \pm \sqrt{(-16)^2-4 \times 3 \times 12}}{2 \times 3}$$

$$x = \frac{16 \pm \sqrt{256-144}}{6} = \frac{16 \pm \sqrt{112}}{6}$$

$$x = \frac{16 \pm 10.6}{6}$$

$$x = \frac{16+10.6}{6} = 4.4 \quad ; \quad x = \frac{16-10.6}{6} = 0.9$$

The value of 'x' as4.4 is note acceptable because it is greater than the initial moles of $C_2H_5OH$

$\boxed{\text{Moles of ester at eq}^m = 0.9}$

**Example – 3:**

In a reaction $A + B \rightleftharpoons 2C$. When equilibrium was attained the concentration was [A] = [B] = 4 moles/dm$^3$ [C] = 6 moles/dm$^3$. Calculate the equilibrium constant $K_C$ and initial conc. of A and B.

<u>Given Data:</u>

Concentration at eq$^m$ [A] = [B] = 4 moles/dm$^3$

Concentration at eq$^m$ [C] = 6 moles/dm$^3$

$$K_c = \frac{[C]^2}{[A][B]} = \frac{[6]^2}{[4][4]} = \frac{36}{16} = 2.25$$



(b) Initial Conc. of A and B

According to the reaction $A + B \rightleftharpoons 2C$ 1 mole of A and 1 mole of B react to form 2 moles of C, so 6 moles of C at equilibrium are produced from 3 moles of A and 3 moles of B. Thus the initial Conc. of A = B = 4 + 3 = 7 moles/dm$^3$

Q. $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

**Calculate the number of moles of $Cl_2$ produced at equilibrium when 1 mole of $PCl_5$ is heated at 250°C in a vessel having a capacity of 10dm$^3$. $K_C$ = 0.041 mole/dm$^3$**

<u>Given Data:</u>

Initial moles of $PCl_5$ = 1 mole

Volume of vessel = 10 dm$^3$

$K_C$ = 0.041 mole/dm$^3$

Moles of $Cl_2$ at eq$^m$ = ?



| | $PCl_5 \rightleftharpoons$ | $PCl_3$ + | $Cl_2$ |
|---|---|---|---|
| Initial moles | 1 mole | zero | zero |
| Moles at eq$^m$ | $1-x$ | x | x |
| Conc. at eq$^m$ | $\left[\frac{1-x}{10}\right]$ | $\left[\frac{x}{10}\right]$ | $\left[\frac{x}{10}\right]$ |

$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]}$$

$$0.041 = \frac{\left[\frac{x}{10}\right]\left[\frac{x}{10}\right]}{\left[\frac{1-x}{10}\right]}$$

$$0.041 = \frac{x^2}{10(1-x)}$$

$$0.041 \times 10(1-x) = x^2$$
$$0.41(1-x) = x^2$$
$$0.41 - 0.41x = x^2$$
$$x^2 + 0.41x - 0.41 = 0$$



$a = 1$ , $b = 0.41$ , $c = -0.41$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
$$x = \frac{-(0.41) \pm \sqrt{(0.41)^2 - 4(1)(-0.41)}}{2(1)}$$
$$x = \frac{-0.41 \pm \sqrt{0.1681 + 1.64}}{2}$$
$$x = \frac{-0.41 \pm \sqrt{1.8081}}{2}$$
$$x = \frac{-0.41 \pm 1.38}{2}$$
$$x = \frac{-0.41 + 1.38}{2}$$

*OR* $$x = \frac{-0.41 - 1.38}{2}$$

$x = 0.895$

negative value of 'x' which concentration not acceptable

$\boxed{x = 0.65}$ mole/dm$^3$

$\boxed{\text{Moles of } Cl_2 \text{ at equilibrium} = 0.65 \text{ moles}}$ **Ans.**

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**Q. Will Cadmium hydroxide precipitate from 0.01M solution of $CdCl_2$ at pH = 9. $K_{S.P}$ of $Cd(OH)_2$ = $2.5 \times 10^{-14}$ mole$^2$/dm$^6$.**

**Solution:**

Conc. of $CdCl_2$ = 0.01 M
pH of solution = 9
$K_{S.P}$ of $Cd(OH)_2$ = $2.5 \times 10^{-14}$ mole$^2$/dm$^6$
Precipitation of $Cd(OH)_2$ = ?

$$Cd(OH)_2 \rightleftharpoons Cd^{+2} + 2OH^-$$
$$K_{S.P} = [Cd^{+2}]\,[OH^-]^2$$

Conc. of $Cd^{+2}$ = 0.01 M (∵ Conc. of $CdCl_2$ = 0.01 M)

For Conc. of $OH^-$ we know that

$$pH + pOH = 14$$
$$pOH = 14 - pH = 14 - 9 = 5$$

As we know that $[OH^-] = 1 \times 10^{-pOH}$

$$[OH^-] = 1 \times 10^{-5}$$

$$\text{Ionic product} = [Cd^{+2}]\,[OH^-]^2$$
$$= [0.01]\,[1 \times 10^{-5}]^2$$
$$= 1 \times 10^{-12} \text{ mole}^3/\text{dm}^9$$

Since the value of ionic product is greater than solubility product therefore precipitate should be formed.

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# FIVE YEAR

**YEAR 2015:**

**Long Question.**

Q.5. State Le-chatelier's Principle. Apply this principle to the manufacture of $NH_3$ by Haber's process.

**YEAR 2014:**

**Short Question.**

(xii) State the law of equilibrium. Derive the expression of $K_C$ for the following reaction.

$$mA + nB \rightleftharpoons xC + yD$$

**Long Question.**

Q.3(c) Predict the effect of change in temperature and pressure on the following equilibrium.

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2 \qquad \Delta H = \text{Positive}$$
$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad \Delta H = \text{Negative}$$

**YEAR 2013:**

**Short Question.**

(xiii) Describe the relationship between $K_C$ and $K_P$.

**Long Question.**

Q.3(b) Sate and explain Le-Chatelier's Principle. How is its applied in contact process.

**YEAR 2012:**

**Short Question.**

(xiii) Discuss the effect of increase in temperature and pressure on the following systems at equilibrium.

(a) $N_2 + 3H_2 \rightleftharpoons 2NH_3 + \text{heat}$ (b) $N_2 + O_2 + \text{heat} \rightleftharpoons 2NO$

**YEAR 2010:**

**Short Question.**

(x) What are the applications of the law of equilibrium?

(xiii) What is meant by common ion Effect? Discuss its application in the precipitation of the second group of basic radicals in qualitative salt analysis.

**YEAR 2009:**

**Long Question.**

Q.4 (a) State and explain Le-Chatelier's Principle and write down its industrial application.

Q.5 (b) Explain common ion Effect related to Ksp Value.

**YEAR 2008:**

Q.6 (a) State the law of mass action and derive the equilibrium constant for

$$aA + bB \rightleftharpoons cC + dD$$

(b) State Le Chatelier's Principle. For the gaseous equilibrium

$$2NO_{(g)} + O_{2(g)} \rightleftharpoons 2NO_{2(g)} \ \Delta H = -Ve$$

Predict only the direction in which the reaction will proceed after the following changes are brought about at equilibrium.

(i) Increasing the concentration of NO

(ii) Decreasing the concentration of $NO_2$

(iii) Increasing the temperature (iv) Increasing the pressure

**YEAR 2007:**

Q.6 (a) State the law of mass action. Apply the law on contact process to derive its equilibrium expression.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

(b) State Le Chatelier's principle. Apply the principle on Haber process interm of pressure and temperature for the maximum yield of $NH_3$.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 + \text{Heat}$$

# PAST PAPER'S NUMERICALS FOR PRACTICE:

## Equilibrium Constant

**Q.1** For the reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$, the equilibrium mixture contains 0.25M $N_2$, 0.15M $H_2$, at 25°C. Calculate the concentration of $NH_3$ at equilibrium when $K_c$ is 9.6. The volume of container is 1 dm$^3$. (1994)

**Ans.** $\boxed{= 0.09 mol/dm^3}$

and 0.32 moles of $Cl_2$ at 250°C. Find the value of $K_c$ for

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$ (1995)

**Ans.** $\boxed{K_C = 0.04}$

**Q.3** For the reaction $H_2 + I_2 \rightleftharpoons 2HI$ $K_C$ is 49. Calculate the concentration of HI at equilibrium when initialy one mole of $H_2$ is mixed with one mole of $I_2$ in one litre flask. (1996)

**Ans.** $\boxed{= 0.77 mole/dm^3}$

**Q.4** $K_C$ for a reaction is 0.0194 and the calculated ratio of the concentration of the reactants and products is 0.0116. Predict the direction of the reaction.
(reaction shift in forward direction) (1996)

**Q.5** 1.5 moles of acetic acid and 1.5 moles of ethyl alcohol were reacted at a certain temperature. At equilibrium, 1 mole of ethylacetate was present in one litre of equilibrium mixture; Calculate the equilibrium constant ($K_C$). ($K_C = 4$)

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$ (1999)

**Q.6** One mole of $PCl_5$ was introduced in a vessel of 10 dm$^3$ capacity at constant temperature. At equilibrium, 0.465 moles of $Cl_2$ gas were present. Calculate $K_C$ for the reaction. $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ (2000)

**Ans.** $\boxed{K_C = 0.04}$

**Q.7** For the reaction $PCl_5 \rightleftharpoons PCl_3 + Cl_2$, the equilibrium mixture at a definite temperature has the partial pressure of gasses as $P_{PCl_5} = 0.36$ atm, $P_{PCl_3} = 0.82$ atm and $P_{Cl_2} = 0.82$ atm. Calculate of $K_p$. (2001)

**Ans.** $\boxed{Kp = 1.86}$

**Q.8** 0.2 mol of A and 0.4 mol of B wore reacted at a certain temperature and allowed to attain equilibrium $A + B \rightleftharpoons 2AB$. The equilibrium mixture contained 0.1 mol A; find $K_C$ if the volume of the container was 2 0 dm$^3$. (2002 P.E)

**Ans.** $\boxed{K_C = 1.33}$

**Q.9** A quantity of $PCl_5$ is heated in a 6.0 dm$^3$ flask at 250°C till the equilibrium $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ is reached. The equilibrium mixture contains 0.16 mol $PCl_3$, 0.16 mol $Cl_2$ and 0.105 mol $PCl_5$; Calculate the equilibrium constant ($K_C$) (2002 P.M)

**Ans.** $\boxed{K_C = 0.04}$

**Q.10** In a reaction $A + B \rightleftharpoons 2C$, When equilibrium is attained, the concentration of B = 4 mol/dm$^3$ and C = 6 mol/dm$^3$. Calculate the initial and equilibrium concentrations of A ($K_C = 2.25$) (2003 P.E) (2015)

**Ans.** $\boxed{Conc\ of\ A = 4 mol/dm^3}$

**Q.11** 60 g of acetic acid and 46 g of ethylalcohol are mixed with each other at constant temperature and allowed to attain equilibrium. At equilibrium 58.2 g of ethylacetate and 12 g of water were present; find the equilibrium constant ($K_C$) (2003 P.M)

**Ans.** $\boxed{K_C = 4}$

Q.12 For the reaction $2HI \rightleftharpoons H_2 + I_2$, one mole of HI is introduced into a vessel at constant temperature. Calculate the number of moles of $I_2$ when equilibrium is reached ($K_C = 0.0156$) **(2004, 2010 Failure)**

Ans. $\boxed{\text{mole of } I_2 = 0.1 \text{ mole}}$

Q.13 The equilibrium constant for the reaction $N_2 + O_2 \rightleftharpoons 2NO$ [illegible] [illegible] equilibrium concentration of the reactants and product when initial concentration of $N_2$ and $O_2$ are 10 moles/dm$^3$. **(2006)**

Ans. Conc of $N_2$ and $O_2 = (10-1.364) = 8.63$ mol/dm$^3$
Conc of NO = 2.728 mol/dm$^3$

Q.14 There are 0.9 mol.dm$^{-3}$ of each of $H_2$ and $I_2$ present in a flask along with 3 mol.dm$^{-3}$ of HI. Predicate the direction in which the reaction moves to achieve equilibrium when $K_C$ is $1.3 \times 10^{-2}$.

$$2HI \rightleftharpoons H_2 + I_2$$ **(2007 Failure)**

Ans. $\boxed{K_c = 9 \times 10^{-2} \text{ reaction shift is B.D}}$

Q.15 In a reaction $A + B \rightleftharpoons 2C$, 7 moles/dm$^3$ of A and 7 moles/dm$^3$ of B were mixed and allowed to attain equilibrium. If $K_C = 2.25$, find out the concentrations of A, B and C at equilibrium state. **(2008)**

Q.16 2 moles of acetic acid and 3 moles of ethylalcohol are mixed at constant temperature until the equilibrium is established; Calculate the equilibrium concentration of ethylcetate ($K_C = 4$)

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$ **(2008 Failure)**

Ans. $\boxed{\text{moles of } CH_3COOC_2H_5 = 1.492 \text{ moles}}$

Q.17 The equilibrium constant expression for the reversible reactions are.

(i) $K_C = \dfrac{[C]^2}{[A][B]}$ (ii) $K_C = \dfrac{[NH_3]^2}{[N_2][H_2]}$ **(2009 Failure)**

Write the balanced chemical equation for the above.

Q.18 Calculate the mass of ethylacetate at 25°C prepared from 60gm of $CH_3COOH$ and 46gm $C_2H_5OH$ ($K_C = 4$) **(2009 Failure)**

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

Ans. $\boxed{\text{Mass of ethylacetate} = 58.66\text{gm}}$

Q.19 When the equilibrium was attained for the reaction $A + B \rightleftharpoons 2C$,
The Concentration of $|A|=|B|$ was 4mol/dm$^3$ and that of C was 6 mole/dm$^3$.
Calculate $K_C$ and the initial concentration of A and B. **(2009)**

Ans. $\boxed{K_C = 2.25 \text{ Initial conc of } A = B = 7 \text{ mol/dm}^3}$

Q.20 The $K_c$ for the reaction $2HI \rightleftharpoons H_2 + I_2$ is $1.3 \times 10^{-2}$. If there are 0.5 mole/dm$^3$ $H_2$, 1.5 mole/dm$^3$ $I_2$ and 5 mole/dm$^3$ HI, Predict the direction in which the reaction moves so as to achieve the equilibrium. **(2010)**

Q.21 $K_c$ for the reaction $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$ at room temperature is 4 calculate the equilibrium concentration of $CH_3COOC_2H_5$ when 1.66 moles of $CH_3COOH$ and 2.17moles of $C_2H_5OH$ are allowed to come to equilibrium. **(2010)**

Q.22 The equilibrium constant expression for a gaseous equilibrium is **(2012)**

$$K_C = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5}$$

Q.23 3 moles of $H_2$ and 4 mole of $I_2$ were heated in a sealed tube at a given temperature at which $K_c$ is 50. If the volume of the tube is $1 dm^3$, determine the composition of the equilibrium

$H_2 + I_2 \rightleftharpoons 2HI$ (2013)

Ans. Conc of $H_2 = 3 - 2.6 = 0.4\ mol/dm^3$

Conc of $I_2 = 4 - 2.6 = 1.4\ mol/dm^3$

Conc of $HI = 2 \times 2.6 = 5.2\ mol/dm^3$

Q.24 [illegible] and [illegible] moles of Oxygen are mixed and heated at 2000°C until the equilibrium is established, 11.28 moles of Nitric Oxide are formed. Calculate the value of equilibrium constant.

$N_2 + O_2 \rightleftharpoons 2NO$

Ans. $\boxed{K_C = 50.21}$

## Solubility Product

Q.25 Should AgCl precipitate from a solution prepared by mixing $400 cm^3$ of 0.1M NaCl and $600 cm^3$ of 0.03M $AgNO_3$? ($K_{sp}$ of AgCl is $1.6 \times 10^{-10} mol^2 . dm^{-6}$)

Ans. $\boxed{\text{ppt are form } Ksp = 7.2 \times 10^{-4}\ mol^2/dm^6}$ (1995, 1997, 2001)

Q.26 The solubility of calcium oxalate is $0.0016\ g/dm^3$. at 25°C, Find its solubility product ($K_{sp}$).

$CaC_2O_4 \rightleftharpoons Ca^{+2} + C_2O_4^{-2}$

Ans. $\boxed{Ksp = 1.56 \times 10^{-10}\ mol^2/dm^6}$ (1998, 2012)

Q.27 The solubility product of $BaSO_4$ is $1.0 \times 10^{-10} mol^2 . dm^{-6}$. Work out the solubility of the salt in $gm/dm^3$ (Mol. Mass of $BaSO_4$ = 233) (2002 P.E)

Ans. $\boxed{2.33 \times 10^{-3}\ gm/dm^3}$

Q.28 Should $PbCrO_4$ precipitate from a solution prepared by mixing $100 cm^3$ of $2.0 \times 10^{-6}$ M $Pb(CH_3COO)_2$ and $900 cm^3$ of $1.5 \times 10^{-8}$ M $Na_2CrO_4$? ($K_{sp}$ of $PbCrO_4$ is $1.8 \times 10^{-14}$) (2002 P.M)

Ans. $\boxed{Ksp = 2.7 \times 10^{-15}\ mol^2/dm^6 \text{ ppt are not farmed}}$

Q.29 What is the solubility of $PbI_2$ in $moles/dm^3$ at 25°C. ($K_{sp}$ of $PbI_2$ is $1 \times 10^{-9}$ $mol^3/dm^9$ and mol. Mass of $PbI_2$ is 461) (2003 P.E)

Ans. $\boxed{6.29 \times 10^{-4}\ mol/dm^3}$

Q.30 The solubility product of AgCl is $9.6 \times 10^{-11} mol^2 . dm^{-6}$ at 25°C. Calculate the solubility of AgCl in $gm/dm^3$ (At. Mass: Ag = 108, Cl = 35.5) (2004)

Ans. $\boxed{1.4 \times 10^{-3}\ g/dm^3}$

Q.31 Will $PbCrO_4$ precipitate from a solution prepared by mixing $200 cm^3$ of $2.5 \times 10^{-4}$ M $Pb(NO_3)_2$ and $600 cm^3$ of $1.5 \times 10^{-8}$ M $K_2CrO_4$? ($K_{sp}$ of $PbCrO_4 = 1.8 \times 10^{-14}$)

Ans. $\boxed{\text{ppt are formed } Ksp = 7.003 \times 10^{-13}\ mol^2/dm^6}$ (2005)

Q.32 Find the $K_{sp}$ of $CaCO_3$ when solubility of $CaCO_3$ is $0.001\ g/dm^3$. (2007)

$CaCO_3 \rightleftharpoons Ca^{+2} + CO_3^{2-}$

Ans. $\boxed{Ksp = 1 \times 10^{-10}\ mol^2/dm^6}$

Q.33 The solubility of AgCl is $1.4 \times 10^{-3}\ g/dm^3$. Calculate $K_{sp}$. (2007 Failure)

Ans. $\boxed{Ksp = 9.6 \times 10^{-11}\ mol^2/dm^6}$

Q.34 The solubility of AgCl at 25°C is $1.4 \times 10^{-3}\ g/dm^3$. What is its solubility product. (2013, 2008)

Ans. $\boxed{Ksp = 9.6 \times 10^{-11}\ mol^2/dm^6}$

Q.35 The solubility product of calcium oxalate is $1.5625 \times 10^{-10}$ mole$^2$/dm$^6$. Calculate its solubility. **(2008 Failure)**

Ans. $\boxed{\text{Solubility} = 1.6 \times 10^{-3}\ g/dm^3}$

Q.36 The given reaction is $PbI_2 \rightleftharpoons Pb^{2+} + 2I$. At 25°C The solubility of $PbI_2 = 0.63 \times 10^{-3}$ mole/dm$^3$. Find the value of Ksp and express it unit.

Ans. $\boxed{Ksp = 1.1 \times 10^{-9}\ mol^3/dm^9}$

Q.37 Calculate the solubility product of $PbCrO_4$ when the solubility of $PbCrO_4$ is $1.0 \times 10^{-3}$ grams/dm$^3$ **(2014)**

Ans. $\boxed{Ksp = 9.579 \times 10^{-12}\ mol^2/dm^6}$

Q.38 What is the ionic concentration of $Ag^+$ ion and $CrO_4^{2-}$ in a saturated solution of $Ag_2CrO_4$ at 25°C Ksp of $AgCrO_4$ is $1.9 \times 10^{-12}$ mole$^3$/dm$^9$ **(2015)**

## MULTIPLE CHOICE QUESTIONS:

(1) The equilibrium mixture contains:

a) Reactant only | b) Products only
c) Both reactant & products | d) No product at all.

(2) Which of the following reaction is not affected by the change in pressure?

a) $2SO_2 + O_2 \rightleftharpoons 2SO_3$. | b) $2O_3 \rightleftharpoons 3O_2$
c) $H_2 + Cl_2 \rightleftharpoons 2HCl$. | d) None of these.

(3) K p > Kc when:

a) moles of product are less | b) moles of product are more
c) moles of reactant are more | d) moles of reactant and product are equal

(4) The value of Kc increases when:

a) [Product] is less | b) [Reactant] is more
c) [Product] is more | d) [Reactant] = [Product]

(5) The reaction of carboxylic acid with alcohol to form ester and water is called:

a) Neutralization | b) Hydrolysis
c) Equilibrium state | d) Esterification.

(6) Formation of Ammonia: $N_2 + 3H_2 \rightleftharpoons 2NH_3$ is favoured at:

a) High pressure | b) Low pressure
c) High Temperature | d) 200°C

(7) The reaction $PCl_3 + Cl_2 \rightleftharpoons PCl_5$ will shift in backward direction if:

a) $[PCl_3]$ is increased | b) $[Cl_2]$ is increased
c) $[PCl_5]$ is increased | d) $[PCl_5]$ is decreased

(8) A substance forms precipitates when its:

a) ionic product > ksp | b) ionic product < ksp
c) ionic product = ksp. | d) kc = ksp

(9) Kc expression for a reaction $2A + B \rightleftharpoons 2C$ will be:

a) $Kc = \frac{[A]^2[B]}{[C]^2}$ b) $Kc = \frac{[C]^2}{[A]^2[B]}$ c) $Kc = \frac{[C]^2}{[A]^2 + [B]}$ d) $Kc = \frac{[2C]}{[2A][B]}$

(10) A solution in which more solute can be added at room temperature is called:

a) Saturated soln b) Unsaturated soln

c) Super = saturated soln d) collidal soln

(11) If the ratio of concentrations of product to reactant at initial state, is less than Kc; the reaction moves in:

a) reverse direction b) forward direction

c) both directions equally d) None of these

(12) The rate of forward reaction in an exothermic reaction will increase on:

a) Increasing temperature b) Decreasing temperature

c) Increasing Pressure d) Decreasing pressure

(13) The unit of ksp for $Mg(OH)_2$ will be:

a) $mol.\ dm^{-3}$ b) $mol^2.\ dm^{-3}$

c) $mol^2.\ dm^{-6}$ d) $mol^3.\ dm^{-9}$

(14) Solubility divided by molecular mass is equal to:

a) concentration b) Ksp

c) Kc d) Kp

(15) A gaseous equilibrium having Kc = Kp proceeds with:

a) increasing volume of product b) decreasing volume of product

c) increasing volume of reactant d) no change in volume

(16) $Kc = 10^{-13}$ shows that:

a) Forward reaction occurs to a negligible extent

b) Very small concentration of product is formed

c) Reactant is fairly stable and does not form product

d) All of above are true.

(17) The Kc value for $H_2 + I_2 \rightleftharpoons 2HI$ averages to:

a) 4 b) 54 c) 5.4 d) 0.01

(18) If initial mole of reactant is 'b' and it forms 'x' mole of product at equilibrium state, the reactant left at this state will be:

a) b + x b) b – x c) x – b d) x + b

(19) If a positive catalyst is added in a reaction, its Kc:

a) increases b) decreases c) does not change d) both a & b

(20) The rate constant (Kc) is a ratio of the two:

a) rate constants b) equilibrium constant

c) [Reactant] / [Product] d) rates

# ANSWER KEY

| | | | |
|---|---|---|---|
| [illegible] | [illegible] | (3) b | (4) c |
| (5) d | (6) a | (7) c | (8) a |
| (9) b | (10) b | (11) a | (12) b |
| (13) d | (14) a | (15) d | (16) d |
| (17) b | (18) b | (19) c | (20) a |



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SESSION
2016-2017

# CLASS-IX

# CHEMISTRY

## Chapter # 7

## SOLUTIONS AND SUSPENSIONS

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# SOLUTION AND SUSPENSION 7

## SOLUTION:

*A homogenous mixture of solute and solvent is called solution.*

*OR*

*[illegible] mixture of two or more substances is called solution.*

*e.g.* Salt and water uniformly mixed to form a solution.
Sugar and water uniformly mixed to form a solution.
Grease and petrol uniformly mixed to form a solution.

## SUSPENSION:

*A heterogeneous mixture of two or more substances is called suspension.*

*e.g.* Sand and water do not mix together, so a suspension is formed.
Oil and water do not mix together, so a suspension is formed.

## SOLUTE:

The substance which is to be dissolved in other substance to form a solution and present in lesser amount is called ***solute.***

*e.g.* Sugar and salt are used as solute in their respective solutions.

## SOLVENT:

The substance which dissolves other substances in it and is present in greater amount is called *solvent.*

*e.g.* Water is used as a solvent in the aqueous solutions of all the substances.

## AQUEOUS SOLUTION:

A solution which contains water as ***solvent*** is called ***aqueous solution.***

## TYPES OF SOLUTION ACCORDING TO AMOUNT OF SOLUTE

Following are the types of solutions according to the amount of solute:

### i) UNSATURATED SOLUTION:

The solution which contains lesser amount of solute than its required capacity at room temperature and pressure is called unsaturated solution.

### ii) SATURATED SOLUTION:

The solution which contains maximum amount of solute and can not dissolve more solute in it at room temperature and pressure is called Saturated solution.

### iii) SUPERSATURATED SOLUTION:

When a saturated solution is heated, more amount of solute can be dissolved in it. Such a solution is called Supersaturated solution.

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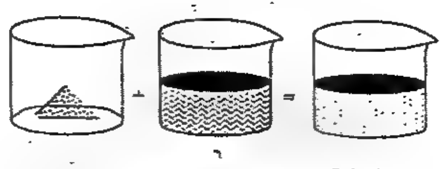
**Preparation of Unsaturated solution:**




Take a few crystals of sugar and dissolve them in a beaker containing 100 ml (cm$^3$) of water. As a result, an unsaturated solution is obtained, because this solution has the capacity to dissolve more crystals of sugar (solute) at room temperature. This solution is called unsaturated solution.

**Preparation of Saturated solution:**

Take some sugar and dissolve in a beaker containing 100 ml (cm$^3$) of water. After dissolving the sugar, add more sugar until the added crystals start to settle down at room temperature. This solution is called saturated solution.

**Preparation of Supersaturated solution:**

Take a saturated solution and dissolve more solute by heating it. Thus a solution is formed which contains more solute than its holding capacity. This solution is called supersaturated solution.

## TYPES OF SOLUTIONS ACCORDING TO CONCENTRATION

### i) DILUTE SOLUTION:

That solution contains less amount of solute than other solution.

### ii) CONCENTRATED SOLUTION:

That solution contains more amount of solute than other solution.

## TYPES OF SOLUTIONS ACCORDING TO PASSAGE OF CURRENT

### i) NON ELECTROLYTE:

A solution through which electric current cannot be passed.
Non-electrolytes are also known as non-polar covalent compounds.
Organic compounds are categorized as non-electrolytes.
*e.g.* sugar solution, alcohol, benzene, thinner (acetone), petrol, kerosene oil, mineral oil, cooking oil, etc.

### ii) ELECTROLYTE:

A solution through which electric current can be passed.
Electrolytes are also known as polar covalent compounds.
Inorganic compounds and ionic compounds are categorized as electrolytes.
*e.g.* acid solutions, alkali solutions and salt solutions.

**Types of Electrolytes:**

a) **Strong Electrolyte:**
A substance that ionizes completely when dissolved in water or in molten form.
*e.g.* HCl, $HNO_3$, $H_2SO_4$, NaOH, KOH, $Ca(OH)_2$, NaCl, etc.

b) **Weak Electrolytes:**
A substance that ionizes partially when dissolved in water or in molten form.
*e.g.* $H_2CO_3$, $CH_3COOH$, $H_3PO_4$, $NH_4OH$, $Mg(OH)_2$, $Cu(OH)_2$, etc.

## EXAMPLES OF MIXTURES

| Solute | Solvent | Examples |
|---|---|---|
| Solid | Solid | Alloys such as Brass (Cu and Zn), Bronze (Cu and Sn). Steel (C and Fe). Glass. etc. |
| Solid | Liquid | Sugar in water, Salt in water, Sea water. etc. |
| Solid | Gas | Smoke (Carbon particles in air). etc. |
| Liquid | Solid | Amalgam (e.g. Mercury in Sodium), Water in jelly powder, etc. |
| Liquid | Liquid | Water in milk, Milk in tea, Alcohol in water. Vinegar (Acetic acid in water), etc. |
| Liquid | Gas | Cloud (Water vapour in air), Steam . etc. |
| Gas | Solid | Hydrogen gas adsorbed over Palladium and Platinum metal surface, etc. |
| Gas | Liquid | Carbonated soft drinks such as Pepsi, Sprite, Ammonia gas in water, Air dissolved in water. etc. |
| Gas | Gas | Air contains 78% $N_2$, 21% $O_2$ and 1% other gases by volume. |

## SOLUBILITY (SOLUBILITY OF SOLUTE):

*"The maximum amount of solute which is required to saturate 100g of solvent (water) at particular temperature and pressure is called Solubility".*

### FACTORS AFFECTING SOLUBILITY:

Following are the factors which affect the solubility of a solute:

(i) Temperature
(ii) Pressure
(iii) Nature of solute and solvent

### i) EFFECT OF TEMPERATURE ON SOLUBILITY:

**a) Solid in liquid:**

The solubility of solid in liquid *increases* with *increase* in temperature.
*e.g.* the solubility of sugar in water at 0°C is 179 g / 100 ml ($cm^3$) whereas at 100°C. it is 487 g / 100ml.

**b) Liquid in liquid:**

The solubility of liquid in liquid slightly *increases* with *increase* in temperature.

**c) Gas in liquid:**

The solubility of gas in liquid *decreases* with *increase* in temperature.
*e.g.* when a glass of cold water is warmed, bubbles of air are seen inside the glass.

## ii) EFFECT OF PRESSURE ON SOLUBILITY:

### a) Solid in liquid:

There is *no effect* of pressure on the solubility of solids in liquids.

### b) Liquid in liquid:

There is *no effect* of pressure on the solubility of liquids in liquids.

### c) Gas in Liquid:

The solubility of a gas in liquid ***increases*** by **increase** in ***pressure***. This is according to ***Henry's law.***

***e.g.*** In soft drinks (carbonated drinks i.e. Pepsi, Sprite, etc.), $CO_2$ is filled with slightly greater than 1 atmospheric pressure because at normal pressure, $CO_2$ is slightly soluble, so more pressure is required.

## HENRY'S LAW:

***Amount of a gas dissolved (m) in a liquid is directly proportional to the pressure (P) of the gas."***

$$m \propto P$$
$$m = kP$$

Where

| | | |
|---|---|---|
| m | : | Amount of gas dissolved |
| k | : | Constant |
| P | : | Pressure |

## iii) EFFECT OF NATURE OF SOLUTE ON SOLUBILITY:

Solubility of substance works with a proverb "***Like Dissolves Like***".

**Therefore:**

- **Ionic solids** are only soluble in ***polar solvents,*** being similar common salt and many other ionic substances are soluble in water because ***water*** is a ***polar*** compound.

- **Polar substances** are soluble in ***polar solvents,*** being similar *HCl* is soluble in water because ***water*** is a ***polar*** compound.

- **Non-polar substances** are soluble in ***non-polar solvents*** being similar like oils, grease, nail polish are soluble in ***non-polar solvents*** like alcohol, benzene, thinner (acetone), petrol, etc.

## CRYSTALLIZATION:

*The process of formation of geometrical shaped solid substances from their aqueous solution is called Crystallization.*

### Properties of Crystalline Substances:

(i) They are homogeneous solids.
(ii) They have sharp melting points.
(iii) They have regular and definite shapes.
(iv) They contain water molecules which are called *water of crystallization.*

### Preparation of Crystals of Copper sulphate $CuSO_4 . 5H_2O$ (Blue Vitriol):

To prepare the crystals of Copper sulphate, first its saturated solution is prepared in a beaker at room temperature and then more quantity of Copper sulphate is added to make supersaturated solution by heating and stirring the solution continuously with a glass rod. Now allow this, supersaturated solution to cool down upto room temperature. On cooling and standing, blue coloured crystals of Copper sulphate are formed. The shape of these crystals can be observed under the microscope.

## PURIFICATION OF SOLIDS BY CRYSTALLIZATION:

### Process of Crystallization:

Following are the steps by which solid can be purified through crystallization:

i) Preparation of Supersaturated solution
ii) Filtration of Hot Supersaturated solution
iii) Formation of Crystals
iv) Filtration and Drying the Crystals

**(i) Preparation of Supersaturated solution:**
Take 50 ml of water in a beaker and add the impure sample (40g) of $KNO_3$ to it. Stir the solution with glass rod. Gently supply heat till the temperature of the solution reaches above 50°C. Stir the solution again at this temperature till most of the solid is dissolved.

**(ii) Filtration of Hot Supersaturated solution:**
Filter the hot solution and collect the residue on the filter paper and collect the filtrate in another beaker.

**(iii) Formation of Crystals:**
On cooling and standing the solution upto room temperature, the crystals of Potassium nitrate will start appearing.

**(iv) Filtration and Drying of the Crystals:**
When no more crystals are formed, filter it again and collect the filtrate in a beaker. Purified crystals of $KNO_3$ are obtained on the filter paper. Dry the crystals by keeping them in between dry filter paper.

**Note:**

The filtrate contains some quantity of the dissolved $KNO_3$ alongwith NaCl, being a soluble impurity.

**iii) Volume By Mass Percentage Concentration** (% by V/M):

If a particular volume of solute is dissolved in a particular mass of solution, the percentage concentration is called Volume by Mass percentage concentration.

$$\% \text{ by V/M} = \frac{\text{Volume of solute}}{} \times 100$$

**e.g.** 20 % V/M of Hydrochloric acid (*HCl*) solution means 20 cm$^3$ of *HCl* dissolved in 100 g of solution.

**iv) Volume By Volume Percentage Concentration:**

If a particular volume of solute is dissolved in a particular volume of solution. the percentage concentration is called Volume by Volume percentage concentration.

$$\% \text{ by V/V} = \frac{\text{Volume of solute}}{\text{Volume of solution}} \times 100$$

**e.g.** 30 % V/V Acetic acid ($CH_3COOH$) solution means 30 cm$^3$ of Acetic acid dissolved in 70cm$^3$ of water to make 100cm$^3$ of solution.

## SUSPENSION:

A heterogeneous mixture of two or more substances is known as Suspension.

### COMMON EXAMPLES OF SUSPENSION IN DAILY LIFE:

| S. # | Name | Mixture (Suspension) |
|---|---|---|
| 1 | **Emulsion** | A suspension of two or more immiscible liquids. |
| 2 | **Foam (froth)** | A suspension of gas (air) in liquid. |
| 3 | **Mud (slime)** | A suspension of fine particles of soil in small amount of liquid. |
| 4 | **Smoke** | A suspension of the particles of Carbon in a gas or air. |

**Soluble:** This word is used for ***solid*** that dissolves in other liquid.
**Insoluble:** This word is used for ***solid*** that doesnot dissolve in other liquid.

**Miscible:** This word is used for ***liquid*** that dissolves in other liquid.
**Immiscible:** This word is used for ***liquid*** that doesnot dissolve in other liquid.

# EXERCISE

**1. Fill in the blanks:**

(i) Solution is a ***homogeneous mixture*** *of* two or more substances.

(ii) The most common solvent in nature is ***water.***

(iii) An ***aqueous*** is the solution when the liquid solvent is water.

(iv) 10% solution [illegible]

(v) ***M*** is the symbol for the concentration unit of molarity.

**2. Tick the correct answer:**

(i) The suspended particles in suspension are generally of the size.

(a) 10nm (b) 100nm *(c) 1200nm √* (d) 1nm

(ii) The sum of the mole fraction of solute and solvent is equal to:

(a) 5 (b) 2 (c) 0 *(d) 1 √*

(iii) Solubility is defined as the amount of solute in gram at a given temperature, dissolved in__________ of the solvent:

(a) 20g *(b) 100g √* (c) 10g (d) 2000g

(iv) The process in which a solid directly changes to vapours is known as:

***(a) Sublimation*** √ (b) Evaporation (c) diffusion (d) Fusion

(v) The solubility of a gas __________ with the rise in temperature.

(a) Increase ***(b) Decrease*** √ (c) remains unchanged

**3. Tick true or false:**

(i) The process of converting a solid into liquid at its melting point is called fusion. *(True)*

(ii) A suspension is a homogenous mixture of two or more substances. *(False)*

(iii) The solution that contains maximum amount of solute in a given solvent at specific temperature is a saturated solution. *(True)*

(iv) Crystals have irregular geometrical shape. *(False)*

(v) Smoke is a suspension of carbon in air. *(True)*



**4. Write answer of the question:**

**(i) Define the following terms:**

(a) Solute

**Answer on page # 3**

(b) Solvent

**Answer on page # 3**

(c) **Solubility**

The maximum amount of a solute that can be to dissolved in 100g of solvent (water) at particular temperature and pressure is called the solubility of the solute.

(d) **Crystallization**

**Answer on page # 7**

**(ii) Name the solute and solvent in the following solutions:**

| | Solution | Solute | Solvent |
|---|---|---|---|
| a | Syrup | Sugar | Water |
| b | Haze | Dust | Air |
| c | Butter | Water | Fat |
| d | Fog | Water Vapour | Air |
| e | Jellies | Water | Fruit Pulp |
| f | Smoke | Carbon Particles | Air |
| g | Sodium Amalgam | Mercury | Sodium |
| h | Cheese | Water | Fat |
| i | Foam | Air | Water |
| j | Mist (Spray) | Water | Air |

**(iii) Discuss the factor affecting the solubility.**

**Answer on Page # 5 and 6**

**(iv) Explain why?**

**(a) Common salt dissolves in water but not in petrol.**
As common salt is an ionic compound while petrol is non-polar covalent compound. due to different nature, common salt is insoluble in petrol.

**(b) Cold drinks are bottled under a $CO_2$ pressure greater than 1 atmosphere.**
Because the $CO_2$ is slightly soluble at 1 atmospheric pressure, it is filled in cold drinks at higher pressure than 1 atmosphere.

**(c) 100ml solution of $KNO_3$ cannot hold more than 37gm of $KNO_3$.**
The solubility of $KNO_3$ at room temperature is 37g. Therefore, 100ml solution of $KNO_3$ cannot hold more than 37g of $KNO_3$ in dissolved state.

**(v) Calculate the molarity of solution containing 16g Glucose per 300 ml solution.**

**DATA**

**Given:**

Mass of solute = 16 g
Volume of solution = 300 ml
Molar mass of Glucose = 180g

| SIDE WORK | | | |
|---|---|---|---|
| $C_6$ = | 12 x 06 | = | 72g |
| $H_{12}$ = | 01 x 12 | = | 12g |
| $O_6$ = | 16 x 06 | = | 96g |
| Molar mass of Glucose = 180g | | | |

**REQUIRED:**

Molarity = ?

**FORMULA:**

$$M = \frac{\text{Mass of solute in gram} \times 1000}{\text{Molar mass} \times \text{Volume of solution in ml or cm}^3}$$

SOLUTION

ANSWER

$$M = \frac{16 \times 1000}{180 \times 300}$$

$$\boxed{Molarity = 0.296\, mol / dm^3}$$

**(vi) Find the mass of Sucrose (Molecular mass = 342) required to be dissolved per 600cm$^3$ solution to prepare a semi-molar solution.**

**DATA:**

**Given:**

| | | |
|---|---|---|
| Molarity | = | semi molar = 0.5 mol /dm$^3$ |
| Volume of solution | = | 600 cm$^3$ |
| Molar mass of Sucrose | = | 342g |

**REQUIRED:**

Mass of solute = ?

**FORMULA:**

$$\text{Mass of solute} = \frac{\text{molarity} \times \text{molar mass of solute} \times \text{volume of solution in cm}^3}{1000}$$

**SOLUTION:**

$$\text{Mass of solute} = \frac{0.5 \times 342 \times 600}{1000}$$

Mass of solute = 102.6 g

$\boxed{\text{Mass of Sucrose} = 102.6\ g}$

**(vii) 5.3g $Na_2CO_3$ was dissolved in 800g water. Calculate the molality of solution.**

**DATA:**

**Given**

| | | |
|---|---|---|
| Mass of solute | = | 5.3 g |
| Mass of solvent | = | 800 g |
| Molar mass of $Na_2CO_3$ | = | 106g |

SIDE WORK

| | | | | |
|---|---|---|---|---|
| $Na_2$ | = | 23 x 02 | = | 46g |
| C | = | 12 x 01 | = | 12g |
| $O_3$ | = | 16 x 03 | = | 48g |

Molar mass of $Na_2CO_3$ = 106g

**REQUIRED:**

Molality = ?

**FORMULA:**

$$\text{Molality} = \frac{\text{Mass of solute (g)} \times 1000}{\text{Molar mass} \times \text{Mass of solvent (g)}}$$

**SOLUTION:**

$$\text{Molality} = \frac{5.3 \times 1000}{106 \times 800}$$

$\boxed{\text{Molality} = 0.0625\ mol / Kg}$

(viii) **It is desired to prepare 3 molal solution of NaOH. What mass of it must be dissolved in 1500g of water?**

**DATA:**

**Given:**

Molality = 3 mol / Kg

Molar mass of NaOH = 40g

**REQUIRED:**

Mass of solute = ?

**FORMULA**

$$\text{Mass of solute} = \frac{\text{molality} \times \text{molar mass of solute} \times \text{mass of solvent (g)}}{1000}$$

**SOLUTION:**

$$\textit{Mass of solute} = \frac{3 \times 40 \times 1500}{1000}$$

Mass of solute = 180 g

$$\boxed{\text{Mass of NaOH} = 180\text{ g}}$$

(ix) **Differentiate between**

(a) Saturated and unsaturated solution (b) Solution and suspension.

## SATURATED AND UNSATURATED SOLUTIONS

| S.# | SATURATED SOLUTION | UNSATURATED SOLUTION |
|---|---|---|
| 1 | It contains the maximum solute that it can hold at normal temperature. | It contains the lesser amount of solute than the holding capacity of solvent. |
| 2 | It is denser than unsaturated solution. | It is lighter than saturated solution. |
| 3 | It can not dissolve more solute in it. | It can dissolve more solute in it. |

## SOLUTION AND SUSPENSION

| S.# | SOLUTION | SUSPENSION |
|---|---|---|
| 1 | The size of their particles is 0.1 nm to 1 nm. | The size of their particles is 1000 nm or more. |
| 2 | They are generally transparent. | They are not transparent. |
| 3 | Their particles do not settle down. | Their particles settle down. |
| 4 | They are homogeneous mixtures. | They are heterogeneous mixtures. |
| 5 | Their components cannot be separated by filtration. | Their components can be separated by filtration. |
| 6 | Particles of solution cannot be seen through low power microscope. | Particles of suspension can be seen through low power microscope. |

**SESSION**
**2016-2017**





# CLASS-IX

# CHEMISTRY

## Chapter # 8

## ELECTROCHEMISTRY

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# ELECTROCHEMISTRY 8

*The branch of chemistry, that deals with the relationship between electricity and chemical reactions i.e. the conversion of electrical energy into chemical energy or vice versa, is known as Electrochemistry.*

*OR*

*The branch of chemistry, which deals with the study of relationship between electric current and chemical ... Electrochemistry.*

## ELECTROLYTES:

*"The chemical compounds which conduct electricity through molten or in aqueous solutions are called electrolyte."*

*OR*

*"A solution through which electric current can be passed is called Electrolyte."*

Inorganic compounds (Ionic and Polar covalent) are categorized as electrolytes.

### Examples:

All acids, bases and salts (in aqueous solutions or fused state) are electrolytes.

| | |
|---|---|
| Hydrochloric acid ($HCl$) | Sulphuric acid ($H_2SO_4$) |
| Sodium hydroxide ($NaOH$) | Sodium chloride ($NaCl$) |
| Copper sulphate ($CuSO_4$) | Acidified Water, etc. |

### Explanation:

Ionic and polar covalent compounds are examples of electrolytes like acids and bases. Salts are ionic compounds and are solids. These solids do not conduct electricity because in the solid state their ions are very tightly packed or held together showing no movement of the ions.

However, when an ionic solid is melted (fused) or dissolved in water, its ions become free to move. This conduction is due to the *free movement of ions.*

No substance can be electrolyzed unless it conducts electricity. But all the conductors are not electrolytes. *Metals are good conductors but they are not Electrolytes.*

## NON – ELECTROLYTES:

*"The chemical compounds which do not conduct electricity through molten or in aqueous solutions are called non-electrolytes."*

*OR*

*"A solution through which electric current cannot be passed is called Non-electrolyte."*

Organic compound (non polar covalent) are categorized as non electrolytes.

*Non metals are bad conductors or insulators but they are not Non-electrolytes.*

### Example:

Sugar solution, Petrol, Benzene, Kerosene oil, cooking oil, pure (distilled) water, etc.

## ELECTRIC CURRENT:

*"The flow of charge per unit time is called Electric Current."*

Its S.I. unit is *Ampere.*

## AMPERE:

*"The amount of current passed through a circuit for one second, that can one Ampere."*

*OR*

*"If one Coulomb charge flows through a conductor in one second, the amount of electric current is called one Ampere."*

## COULOMB:

*If one Ampere of electric current is passed for one second, then the quantity of charge is known one as Coulomb.*

Its S.I. unit is Coulomb.

Electric charge = A x t

1 Coulomb (C) = (1 Ampere) x (1 second)

## FARADAY:

*96500 Coulombs charge, passed through an electrolyte, is called One Faraday (F).*
*1F = 96500 C*

## ELECTROCHEMICAL EQUIVALENT (Z):

*The amount of a substance deposited or liberated during electrolysis, when one Coulomb charge is passed through an electrolyte, is called Electrochemical Equivalent.*

Its S.I. unit is Kg / Coulomb (Kg/C).

**Every element has its own electrochemical equivalent.**

## FARADAY'S FIRST LAW OF ELECTROLYSIS:

*"The amount of any substance deposited or liberated at an electrode during electrolysis is directly proportional to the amount of electric current and the time."*

*OR*

*"The mass of an element, discharged during electrolysis, is directly proportional to the time and the magnitude of electric current."*

### Explanation:

According to the law,

$$W \propto A \times t$$

$$W = Z \times A \times t$$

Where

W = mass of the element deposited or liberated

Z = electrochemical equivalent of the substance

A = amount of electric current in ampere

t = time in seconds

## FARADAY'S SECOND LAW OF ELECTROLYSIS:

*"The masses of different substances deposited or liberated, when the same quantity of current is passed through different electrolytes, connected in series, are proportional to their equivalent masses."*

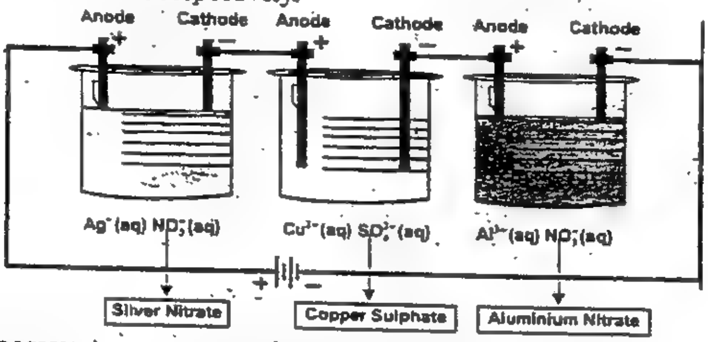
### Explanation:

Consider three different electrolytes, $AgNO_3$, $CuSO_4$ and Al $(NO_3)_3$ solutions, connected in series. Same quantity of current is passed through them and then the masses of Ag, Cu and Al deposited on their respective electrodes are found to be ... masses.

According to Faraday, if exactly 96500 Coulombs (1F) of electric charge is passed then the mass of an element deposited is equal to its equivalent mass.

### For example:

When 96500 Coulomb charge is passed through the electrolytes, **108g of Ag, 31.75g of Cu and 9g of Al** is deposited at their cathodes. These masses which are equal to their equivalent masses respectively.




## RELATIONSHIP BETWEEN EQUIVALENT MASS AND ELECTROCHEMICAL EQUIVALENT:

Since 96500 Coulomb or 1Faraday (1F) electric charge is required to liberate one gram equivalent mass of a substance, it is clear that the gram equivalent mass of a substance is 96500 times greater than its electrochemical equivalent.

$$\text{Gram Equivalent Mass} = 96500 \times \text{E.C.E. (Z)}$$

In other words $e = 96500 \times Z$ or $e = F \times Z$

$$Z = \frac{e}{96500} \quad \text{or} \quad Z = \frac{e}{F}$$

Where
$e$ = Gram Equivalent Mass
$F$ = Faraday = 96500 Coulomb
$Z$ = E.C.E. = Electrochemical equivalent

### Electrochemical Equivalent:

| | | | |
|---|---|---|---|
| Silver = | 0.001118 g/C | = $1.118 \times 10^{-3}$ g/C | = $1.118 \times 10^{-6}$ Kg/C |
| Copper = | 0.000329 g/C | = $3.29 \times 10^{-4}$ g/C | = $3.29 \times 10^{-7}$ Kg/C |
| Aluminium = | 0.0000932 g/C | = $9.32 \times 10^{-5}$ g/C | = $9.32 \times 10^{-8}$ Kg/C |
| Gold = | 0.00102 g/C | = $1.02 \times 10^{-3}$ g/C | = $1.02 \times 10^{-6}$ Kg/C |
| Nickel = | 0.000304 g/C | = $3.04 \times 10^{-4}$ g/C | = $3.04 \times 10^{-7}$ Kg/C |
| Chromium = | 0.000538 g/C | = $5.38 \times 10^{-4}$ g/C | = $5.38 \times 10^{-7}$ Kg/C |

## Equivalent Masses of Some Elements:

Equivalent mass of an element $= \dfrac{\text{Atomic mass of the element}}{\text{valency of the element}}$

(i) Equivalent mass of Silver $= \dfrac{108}{1} = 108\text{ g}$

(ii) $\dfrac{63.5}{2}$

(iii) Equivalent mass of Aluminium $= \dfrac{27}{3} = 09\text{g}$

## ELECTROLYSIS (ELECTROLYTIC CONDUCTION):

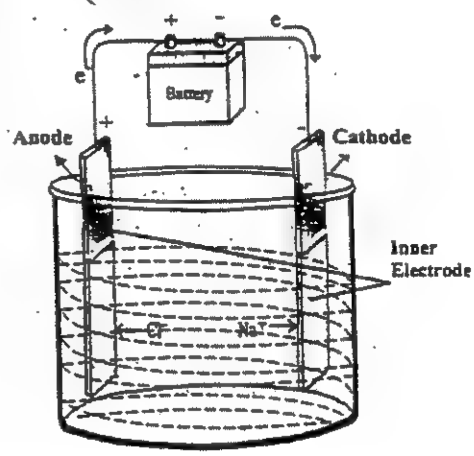
***"When electric current is passed through an electrolyte, the dissociated ions travel towards their respective electrodes so that they become neutral by current. This is called electrolysis."***

***OR***

***"Movement of the ions of an electrolyte towards their respective electrodes and their deposition or liberation as neutral species under the influence of electric current is called electrolysis."***

### 1. Electrolysis of Molten Sodium chloride:

Sodium chloride melts at **800°C.** The molten salt contains Sodium (metal) positive ion ($Na^+$) and Chloride (non-metal) negative ion ($Cl^-$). The ionization reaction is as follows:




$$NaCl_{(s)} \xrightarrow[800°C]{Fused} Na^+_{(l)} + Cl^-_{(l)}$$

When an electric current is passed, the following reactions take place at the two electrodes:

### At the Cathode: (Reduction):

Positively charged Sodium ($Na^+$) ions move towards the cathode and gain electrons to form neutral molten sodium metal i.e. reduction takes place.

Sodium ion + electron ⟶ Sodium metal

$$Na^+_{(l)} + e^- \xrightarrow{800°C} Na_{(s)}$$

### At the Anode: (Oxidation):

Negatively charged Chloride ions ($Cl^-$) move towards the anode and lose the electrons to form neutral Chlorine gas ($Cl_2$) i.e. oxidation takes place.

$$2Cl^-_{(l)} \longrightarrow Cl_{2(g)} + 2e^-$$

***The overall reaction can be described as:***

$2Na^+_{(l)} + 2e^- \longrightarrow 2Na_{(s)}$ Cathode reaction

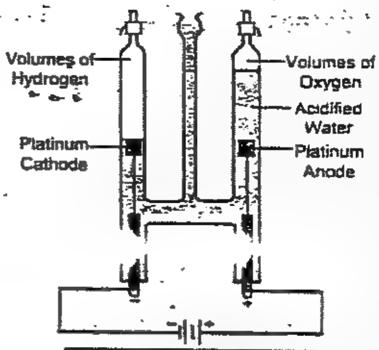
$2Cl^-_{(l)} \longrightarrow Cl_{2(g)} + 2e^-$ Anode reaction

**Net Reaction:** $2Na^+_{(l)} + 2Cl^-_{(l)} \longrightarrow \underset{\text{At Cathode}}{2Na_{(l)}} + \underset{\text{At Anode}}{Cl_{2(g)}}$

## 2. Electrolysis of Water:

Pure water does not conduct electricity because it ionizes partially into ions. Few drops of acid or base are added which dissociate water into its ions.

When water is electrolysed, Hydrogen gas is produced at the cathode and Oxygen gas is produced at the anode.




ELECTROLYSIS OF WATER

Consider an electrolytic cell containing acidified water. Two electrodes are dipped in acidified water. In the presence of few drops of acid, water ionizes as:

$$2H_2O_{(l)} \overset{\text{Acid}}{\rightleftharpoons} \underset{\text{Hydronium ion}}{H_3O^+_{(aq)}} + \underset{\text{Hydroxide ion}}{OH^-_{(aq)}}$$

When electric current is passed through the solution, the following reactions take place:

### At Cathode:

Positively charged Hydronium or Oxonium ions ($H_3O^+$) move towards the cathode and gain electrons. As a result, $H_2$ gas is liberated at the cathode.

$$2H_3O^+_{(aq)} + 2e^- \longrightarrow 2H_2O_{(l)} + H_{2(g)}\uparrow$$

### At Anode:

Hydroxide ions ($OH^-$) move towards the anode. $OH^-$ ions lose electrons at the anode. As a result, $O_2$ gas is liberated at the anode.

$$4OH^-_{(aq)} + 4e^- \longrightarrow 2H_2O_{(l)} + O_{2(g)}\uparrow$$

The overall reaction should be balanced according to gain and loss of electrons at the two electrodes. So the cathode reaction is multiplied by 2 and then added to the anode reaction.

$$2\,[\,2H_3O^+_{(aq)} + 2e^- \longrightarrow 2H_2O_{(l)} + H_{2(g)}\,]$$

To obtain overall reaction, both reactions should be added

$$4H_3O^+_{(aq)} + 4e^- \longrightarrow 4H_2O_{(l)} + 2H_{2(g)}$$
$$4OH^-_{(aq)} \longrightarrow 2H_2O_{(l)} + O_{2(g)} + 4e^-$$

$$4H_3O^+_{(aq)} + 4OH^-_{(aq)} \longrightarrow 6H_2O_{(l)} + O_{2(g)}\uparrow + 2H_{2(g)}\uparrow$$

$4H_3O^+$ and $4OH^-$ together will be equal to $8H_2O$, so

$$8H_2O_{(l)} \longrightarrow 6H_2O_{(l)} + 2H_{2(g)} + O_{2(g)}$$

Now overall reaction can be written as:

$$2H_2O_{(l)} \xrightarrow[\text{Acidified}]{\text{Current}} \underset{\text{At Cathode}}{2H_{2(g)}} + \underset{\text{At Anode}}{O_{2(g)}}$$

### RESULT:

The result of the electrolysis of acidified water confirmed that two volumes of Hydrogen gas and one volume of Oxygen gas are produced during electrolysis.

**NOTE:** Humphrey Davy confirmed that the formula of water is $H_2O$ (2:1 ratio of Hydrogen and Oxygen gas by volume) through electrolysis.

## USES (APPLICATIONS) OF ELECTROLYSIS:

Electrolysis is an important process used:

(i) for the extraction of certain metals from their ores (minerals).

(ii) for Electroplating.

### (i) Extraction of Aluminium:

*Al* (Aluminium) metal is extracted by the electrolysis of Alumina ($Al_2O_3$) which is obtained from Bauxite ($Al_2O_3 . nH_2O$).

### (ii) Extraction of Sodium:

*Na* (Sodium) metal is extracted by the electrolysis of molten Sodium chloride. Sodium (Na) metal is obtained at the cathode by Down's process.

### (iii) Extraction of Copper:

*Cu* (Impure or blister Copper) metal is purified by the process of electrolysis. Pure copper metal is deposited at the cathode.

## ELECTROPLATING:

***The coating of one metal on the surface of other metal through the electric current or by electrolysis is called Electroplating.***

***OR***

***Deposition of a thin layer of a superior and corrosion less metal over an inferior or cheap metal by the process of electrolysis is called Electroplating.***

### Conditions:

The object to be electroplated is connected with the cathode. It is also called **baser metal** like Iron, Steel, etc.

The metal which is coated on the object is connected with the anode. It is also called **coat metal** like Silver, Gold, Nickel, Chromium, Tin, etc.

The electrolyte used, should contain the ions of the metal, of which the anode is made.

### Advantage:

The cost of the finished product is much lower than the one if the object is entirely made of the coat metal. **Gold-coated object is much cheaper than the gold object.**



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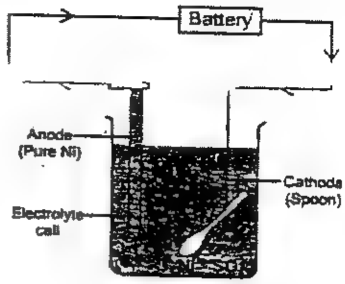
# APPLICATIONS (USES) OF ELECTROPLATING:

## 1. NICKEL PLATING:

Nickel metal is coated over baser metal (spoon) by the process of electroplating.

$Ni_{(s)} \longrightarrow Ni_{(s)}$
(anode) (cathode)




A piece of pure Nickel metal is used as the anode and the spoon or any object to be plated is the made as cathode. A solution of Nickel sulphate ($NiSO_4$) is used as the electrolyte in the cell. The two electrodes are joined to a battery. On passing the electric current, the *Ni* anode dissolves in the solution forming $Ni^{2+}$ ions by the loss of electrons (oxidation). $Ni^{2+}$ ions from the solution move towards the cathode, where they gain electrons (reduction) and *Ni* metal is deposited on the surface of the spoon (cathode).

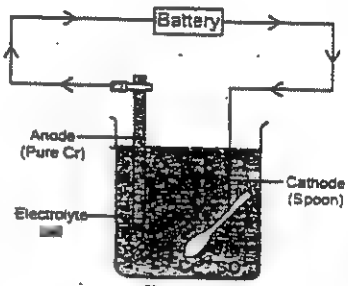
$Ni_{(s)} \longrightarrow Ni^{2+}_{(aq)} + 2e^-$ [At Anode (Oxidation)]

$Ni^{2+}_{(aq)} + 2e^- \longrightarrow Ni_{(s)}$ [At Cathode (Reduction)]

The overall reaction is simply the transfer of *Ni* as $Ni^{2+}$ through $NiSO_4$ solution towards the cathode i.e. spoon is coated with *Ni* metal.

## 2. CHROMIUM PLATING (CHROME PLATING):

Chromium metal is coated over baser metal (spoon) by the process of electroplating.



Battery

A piece of pure **Chromium** metal is used as anode and the spoon or any object to be plated is made as cathode. A solution of Chromium sulphate [$Cr_2(SO_4)_3$] is used as the electrolyte in the cell. The two electrodes are joined to a battery. On passing the electric current, the *Cr* anode dissolves in the solution forming $Cr^{3+}$ ions by the loss of electrons (oxidation). $Cr^{3+}$ ions from the solution move towards the cathode, where they gain electrons (reduction) and *Cr* metal is deposited on the surface of the spoon (cathode).

$Cr_{(s)} \longrightarrow Cr^{3+}_{(aq)} + 3e^-$ [At Anode (Oxidation)]

$Cr^{3+}_{(aq)} + 3e^- \longrightarrow Cr_{(s)}$ [At Cathode (Reduction)]

# ELECTROCHEMICAL CELLS:

*"A device that produces electrical energy (current) through chemical energy is called Electrochemical Cell."*

# TYPES OF ELECTROCHEMICAL CELLS:

1. **Galvanic or Voltaic cell** 2. **Dry cell**

## 1. GALVANIC OR VOLTAIC CELL:

An electrochemical cell which contains water as solvent is called Galvanic or Voltaic cell. **Galvanic cell is a primary as well as irreversible cell.**

## 2. DRY CELL:

An electrochemical cell which contains paste or viscous mixture but does not contain water as solvent is called dry cell. **Dry cell is a primary as well as irreversible cell.**

A battery is a collection of two or more **Galvanic or Voltaic cells.**

A battery is an assembly of two or more Galvanic or Voltaic cells which are connected together in series. **Batteries are secondary as well as reversible cells.**

## DANIEL CELL:

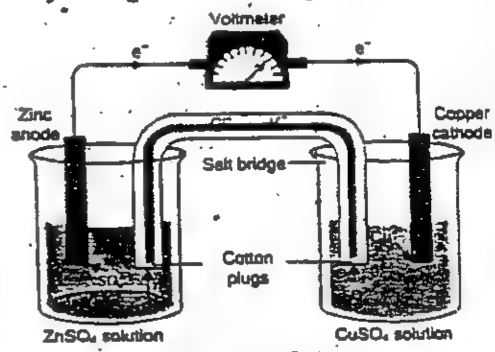
A Daniel cell is an example of Galvanic or Voltaic cell which is used to convert chemical energy into electrical energy spontaneously.

### Construction:

Daniel cell consists of two half cells. One half cell is Zinc rod (Zn-metal) dipped in 1M $ZnSO_4$ solution and the other half cell is Copper rod (Cu-metal) dipped in 1M $CuSO_4$ solution. The two half cells or single electrodes are connected together by a porous partition or a salt bridge to form a complete cell.

### Process / Working:

Both the electrodes are connected externally through a voltmeter by means of metal wire. The cell starts producing electric current at once. **Zn-metal** rod undergoes oxidation to form $Zn^{2+}$ ions by the loss of two electrons (oxidation takes place), these ions go into $ZnSO_4$ solution. Zn-metal rod acts as the **anode or negative** electrode. The electrons travel through the wire externally to **Cu-metal** rod. These electrons are accepted (reduction takes place) by $Cu^{2+}$ ions of $CuSO_4$ solution and Copper metal is deposited at **Cu electrode** which acts as the **cathode or positive** electrode.




DANIEL CELL
(Zn - Cu voltaic cell)

### Conclusion:

In this process, **Zn-electrode** dissolves in the solution of $ZnSO_4$ and reduces in size (oxidation takes place), while **Cu-electrode** increases in size (reduction takes place) due to the deposition of **Cu- ions** in neutral condition.

## CELL REACTION:

At Zn – Electrode (Anode)

$$Zn_{(s)} \longrightarrow Zn^{2+}_{(aq)} + 2e^-$$

At Cu - Electrode (Cathode)

$$Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$$

The net reaction is the sum of two half cell reactions.

$$Zn_{(s)} + Cu^{2+}_{(aq)} \longrightarrow Zn^{2+}_{(aq)} + Cu_{(s)}$$

## FUNCTION OF SALT BRIDGE:

The function of salt bridge or porous partition is to prevent the mixing of the two solutions ($ZnSO_4$ and $CuSO_4$) and to allow the ions to move through it from one part to another. $Zn^{2+}$ ions from the anode compartment move towards the cathode compartment while negative ions $SO_4^{2-}$ ions move from the cathode compartment to the anode compartment through the porous partition or salt bridge. It maintains the electrical conductivity in the two electrolytic solutions.

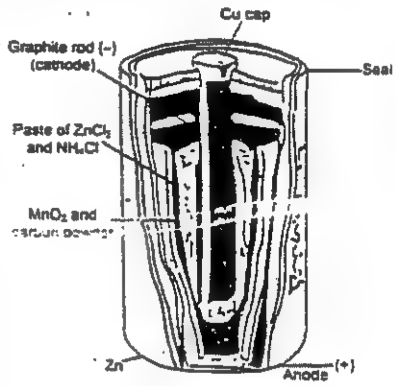
**The cell voltage in Daniel cell is 1.10 volt.**

## DRY CELL:

An electrochemical cell which contains paste or viscous mixture but does not contain water as solvent is called dry cell. **Dry cell is a primary as well as irreversible cell.**

### Construction:

In a dry cell, an outer zinc case (container) acts as the ***anode*** and inner carbon (graphite) rod acts as the ***cathode***. The graphite rod is surrounded by a mixture of manganese dioxide ($MnO_2$) and Carbon powder. The electrolyte is a moist paste of Ammonium chloride ($NH_4Cl$) and Zinc chloride ($ZnCl_2$). The concentrated electrolytic solution is thickened into a gel-like paste by an agent such as ***starch***. The upper top position of the cell is sealed with wax (sealing material). A copper cap is fitted on the top of Carbon rod (cathode) to make the electrical contact. The zinc case is wrapped with a safety cover. ***This cell is called a dry cell because there is no free flowing liquid.***




DRY CELL

### Process / Working:

When Zinc and graphite electrodes are connected by a metallic wire, **Zn** gets oxidized to form $Zn^{2+}$ ions which pass into the wet paste leaving behind electrons on the **Zn** case and the electrons move from **Zn electrode** to **Carbon electrode** through the external circuit. The cell reactions are complex.

## USES:

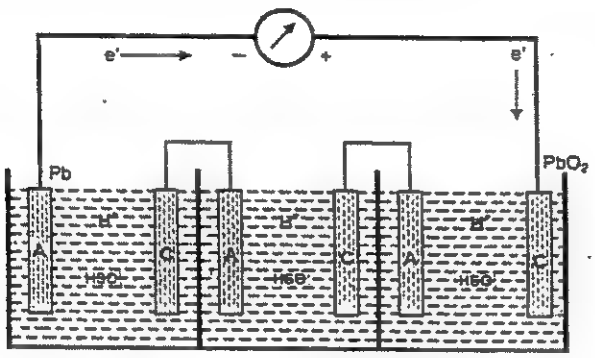
It is used in most of the flashlights, calculators, clocks, transistors and in portable electronic devices.

## BATTERIES:

A battery is a collection of two or more **Galvanic or Voltaic cells.**

A battery is an assembly of two or more Galvanic or Voltaic cells which are connected together in series. **Batteries are secondary as well as reversible cells.**

Lead storage battery is used in automobiles. It is a secondary cell and is a reversible cell which can be restored to its original condition. The battery can be used through repeated cycles of discharging and recharging.




LEAD STORAGE BATTERY



## Construction:

In lead storage battery, the **anodes are lead (Pb)** alloy and the **cathodes** are made of **red lead dioxide ($PbO_2$).** The electrolyte is dilute **Sulphuric acid ($H_2SO_4$)** which has 30% concentration.

There are several anodes and several cathodes which are connected together in series; about six cells are connected together. Each cell has a voltage of 2V and overall voltage when six cells are connected together in series would be **12V.**

## Discharging (Working):

As the cell reaction procedes, $PbSO_{4(s)}$ precipitates and partially coats both the electrodes, Sulphuric acid becomes diluted because more and more water is formed. The battery is said to be discharged.

## Recharging:

Now, by connecting the battery to an external electrical source, we can force the electrons to flow in the opposite direction, i.e. the net cell reaction can be reversed and the battery is recharged.

**Q.1** A current of 0.5 ampere was passed through a solution of $CuSO_4$ for one hour. Calculate the mass of Copper metal deposited on the cathode. Electrochemical equivalent of Cu= 0.000329 g/C = $3.29 \times 10^{-4}$ g/C or $3.294 \times 10^{-7}$ Kg/C.

**DATA:**

**Given:**

Current in ampere (A) = 0.5 ampere

Time in second (1 hr) = $1 \times 60 \times 60 = 3600$ s

**REQUIRED:**

Mass of Copper deposited = W?

**FORMULA:**

$W = Z \times A \times t$

**Solution:**

$W = 3.294 \times 10^{-7} \times 0.5 \times 3600$

$W = 5929.2 \times 10^{-7}$ Kg

$W = 5.929 \times 10^{-4}$ Kg

Mass of copper metal deposited = $5.929 \times 10^{-4}$ Kg or 0.5929 g

**Answer:**

$\boxed{W = 5.929 \times 10^{-4} \text{ Kg or } 0.5929 \text{ g}}$

**Q.2** A current of 10 amperes was passed for 15 minutes in a solution of Silver nitrate ($AgNO_3$). The mass of Silver deposited was found to be $1.0062 \times 10^{-2}$Kg. Calculate the electrochemical equivalent (Z) of Ag metal.

**DATA:**

**Given:**

Current = 10 ampere

Time in seconds (15 minutes) = $15 \times 60 = 900$ s

Mass of Ag metal deposited (w) = $1.0062 \times 10^{-2}$ Kg = 10.062g

**REQUIRED:**

- Electrochemical equivalent = Z = ?

**FORMULA:**

$W = Z \times A \times t$

$$Z = \frac{W}{A \times t}$$

**Solution:**

$$Z = \frac{10.062}{10 \times 900}$$

$Z = 0.001118$ g/C or $1.11 \times 10^{-3}$ g/C

**Answer:**

$\boxed{Z = 0.001118 \text{ g/C or } 1.118 \times 10^{-6} \text{ kg/C}}$

**Q.3** **A constant current was passed for 5 hours through $CuSO_4$ and 404 mg of Cu was deposited. Calculate the current passed.**

**DATA:**

**Given:**

Amount of Cu deposited = W = 404mg = 0.404g

[illegible]

Gram equivalent mass of Cu = $\frac{63.5}{2}$ = 31.75 g

**REQUIRED:**

The Amount of Electric Current = ?

**FORMULA:**

$$A = \frac{F \times W}{e \times t}$$

**Solution:**

$$A = \frac{96500 \times 0.404}{31.75 \times 18000}$$

$$A = \frac{38986}{571500}$$

$$A = 0.0682 \text{ Ampere or } 6.82 \times 10^{-2} \text{ A}$$

**Answer:**

$\boxed{\text{Electric current passed} = 0.0682 \text{ Ampere or } 6.82 \times 10^{-2} \text{ A}}$

**METHOD 2**

**Solution:**

According to cathode reaction,

63.5g of Cu is deposited by 2 F electric charges.

$\therefore$ 0.404g of Cu is deposited by $\frac{2}{63.5} \times 0.404$

$= 0.0127$ F

We know

1F = 96, 500 coulomb

$\therefore 0.0127F = 0.0127 \times 96500$

$= 1225.6C$

$\therefore$ Coulomb = Ampere x t sec. (time = 5hours)

$$\text{Ampere} = \frac{\text{coulomb}}{\text{time}}$$

$$= \frac{1225.6}{18000}$$

$$= \boxed{6.82 \times 10^{-2} \text{ A}} \text{ Ans.}$$

**Q.2 How many grams of Oxygen gas are liberated by the electrolysis of water after passing 0.0565 ampere for 185 seconds.**

Hint: Equation:

$$2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$$

According to the equation, (four) Faraday is required to liberate 32 g of $O_2$.

**DATA:**

**Given:**

Current in ampere = 0.0565 A

Time in second = 185 Sec

Gram Equivalent mass of Oxygen = $e = \frac{32}{4}$

$e = 8gm$

**REQUIRED:**

Mass of Oxygen gas liberated = W = ?

**FORMULA:**

$$W = \frac{A \times e \times t}{96500}$$

**Solution:**

$$W = \frac{83.62}{96500}$$

$W = 0.000866$ g

$W = 8.66 \times 10^{-4}$ g

**Answer:**

$\boxed{W = 0.000866 \text{ g or } 8.66 \times 10^{-4} \text{ g}}$

**METHOD 2**

**Equation:**

$$2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$$

According to the equation (four) Faraday is required to liberate 32g of $O_2$

**DATA:**

Current in ampere = 0.0565 A

Time in second = 185 Sec

**Solution:**

Coulomb = ampere x time (s)

= 0.0565 x 185

= 10.45 C.

$$F = \frac{C}{96500}$$

$$= \frac{10.45}{96500}$$

= 0.000108 F

Now 4 F electric charge liberates $\frac{32}{4} \times 0.00010829$

$\therefore$ 0.000108 electric charges liberated 0.000866g

Mass of Oxygen liberated = $8.66 \times 10^{-4}$ g $O_2$

**Answer:**

$\boxed{W = 0.000866 \text{ g or } 8.66 \times 10^{-4} \text{ g}}$

# EXERCISE

**1. Fill in the blanks:**

(i) The substance used for electrolysis is called ***Electrolvte*** .

(ii) When molten [illegible]

cathode.

(iii) One Faraday is equivalent to ***96500*** Coulombs.

(iv) The electrolyte in lead storage battery is ***Sulphuric acid***

(v) Dry cell is a ***Primary*** cell.

**2. Write true or false:**

(i) Sugar is an electrolyte. ***False***

(ii) Electrolytic conductance is also known as electrolysis. ***True***

(iii) Z is called the electrochemical equivalent. ***True***

(iv) The unit of electrochemical equivalent is ampere x second. ***False***

(v) Daniel cell is a voltaic cell. ***True***

(vi) Lead storage battery is a primary cell. ***False.***

**3. Write answers of the following questions:**

(i) Define the following terms: **Answers:**

| | | |
|---|---|---|
| (a) | Electrolysis | **See Page # 6** |
| (b) | Electrochemical cell | **See Page # 9** |
| (c) | Coulomb | **See Page # 4** |
| (d) | Electrochemical equivalent | **See Page # 4** |
| (e) | Primary cell | **See Page # 10** |
| (f) | Electroplating | **See Page # 8** |

(ii) Predict what would be formed (i) at the anode and (ii) at the cathode when each of the following molten salts are electrolysed using inert electrodes.

(a) NaCl

**Ans.** Na metal deposits at the Cathode and $Cl_2$ gas liberates at the anode.

(b) $MgBr_2$

**Ans.** Mg metal deposits at the Cathode and $Br_2$ gas liberates at the anode.

(c) $CaCl_2$

**Ans.** Ca metal deposits at the Cathode and $Cl_2$ gas liberates at the anode.

(iii) State and explain Faraday's first law of electrolysis.

**Ans.** See Page# 4

(iv) Calculate the amount of Silver deposited when 10 ampere of current is passed for 50 minutes through a solution of $AgNO_3$.

(Z of Ag = 0.001118 g/C)

**Ans.** $w = Z \times A \times t$

Where $Z = 0.001118$ g/C

$A$ = current = 10 ampere

$t = 50$ minutes $= 50 \times 60 = 3000$ sec

$w = 0.00118 \times 10 \times 3000$

$\boxed{w = 35.4g}$ **Answer**



(v) Describe the construction and working of a dry cell.

**Ans.** See Page # 11

(vi) What happens when electric current is passed through acidified water?

Give the reactions at the two electrodes and the products at the cathode and the anode.

**Ans.** See Page # 7

(vii) Predict the net electrolysis reaction when molten NaCl is electrolyzed.

**Ans.** See Page # 6

(viii) Describe the process of Nickel plating.

**Ans:** See Page # 9

(ix) What is the function of a salt bridge or porous partition in an electrochemical cell?

**Ans:** See Page # 11

(x) Which of the following pairs of terms have the same meaning and which have a different meaning?

a = Voltaic Cell and Galvanic Cell.

b = Electrolytic Cell and Electrochemical Cell.

c = Cell and Battery.



**Answer**

a = Same.

b = Same.

c = Different.

**(xi)** What is the difference between a primary and a secondary cell? Give an example of each. Discuss Lead – storage battery.

**Answer:**

**Primary Cell:**

A device that produces electric energy (current) through irreversible chemical reaction is called Primary cell. It is irreversible cell. This cell can not be recharged.

**Secondary Cell:**

A device that produces electric energy (current) through reversible chemical reaction is called Secondary cell. It is reversible. This cell can be recharged.

**Example:**

Primary cell = Dry cell

Secondary cell = Lead Storage Battery (Car-Battery).

For description of Lead Storage Batteries *SEE PAGE #12.*

**(xii)** When molten NaCl is electrolysed. Sodium metal is liberated at the cathode by the reaction $Na^+ + e^- \rightarrow Na_{(s)}$. How many grams of Sodium are liberated when $5 \times 10^3$ C of electric charge is passed through the cell?

**Data:**

**Given:**

Charge = $5 \times 10^3$ C

Gram Equivalent mass of sodium = 23g

**Required:**

Mass of Sodium deposited.

**Solution:**

As know that 1Faraday electricity can produce a mass of an element equal to its Gram Equivalent mass and 1 Faraday is equal to 96500 coulombs

There fore

1 C charge can liberate $\frac{23}{96500}$

$5 \times 10^3$ C can liberate $\frac{23}{96500} \times 5 \times 10^3$

$5 \times 10^3$ C can liberate $0.00119 \times 10^3$g

$5 \times 10^3$ C can liberate 1.19g

**Answer:** $\boxed{5 \times 10^3 \text{ C liberated } 1.19\text{g of Na}}$

SESSION
2016-2017

PRACTICAL CENTRE KARACHI

# CLASS-IX

# CHEMISTRY

## Chapter # 9

## ACIDS, BASES AND SALTS

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# ACIDS, BASES AND SALTS 9

## INTRODUCTION:

Acids and Bases were recognized as the two groups of substances in the $15^{th}$ century by Muslim chemists. It was recognized that substances having ***sour taste*** were called ***Acids***. (Acid means Sour in Latin). They also recognized another group of substances having *bitter taste* and used as cleaning agents were called Bases. Neutralization was also recognized in early $16^{th}$ century.

## ACIDS IN DAILY LIFE:

| Source | Organic acid | Source | Organic acid |
|---|---|---|---|
| Apples | Maleic Acid | Sour milk | Lactic acid |
| Butter | Butyric acid | Vinegar | Acetic Acid |
| Orange, Grape (Citrus Fruits) | Citric Acid<br>Ascorbic Acid ($C_6H_8O_6$)<br>(Vitamin-C) | Lemon | Citric Acid<br>Ascorbic Acid ($C_6H_8O_6$)<br>(Vitamin-C) |

Hydrochloric acid (HCl), Sulphuric acid ($H_2SO_4$) and Nitric acid ($HNO_3$) are called **inorganic** or **mineral acids**. In human stomach, 0.4% of gastric juice contains HCl for proper digestion.

## BASES IN DAILY LIFE:

Bases are also common in use as household Ammonia solution ($NH_3 + H_2O$) is used as cleaning agent. Caustic soda (NaOH) is used for cleaning sink-drains. Milk of Magnesia $Mg(OH)_2$ is used as an anti-acid (antacid).

## SALTS:

An ionic compound produced by neutralization between acid and base having positive and negative ions is called salt.

Salts are not only neutral; they may behave like acids or bases.

## PROPERTIES OF ACIDS AND BASES

### PHYSICAL PROPERTIES OF ACIDS:

1. Acids have sour taste.
2. Acids turn blue litmus to red.
3. Colourless phenolphthalein remains colourless in acids.
4. Methyl orange changes its colour from orange to reddish or pink.
5. Acids are electrolytes (their aqueous solutions conduct electricity).
6. Concentrated acids destroy fabrics, skin and human and plant tissues, etc.

## CHEMICAL PROPERTIES OF ACIDS:

Acids react with bases, non metals, metal carbonates and bicarbonates. Some of their chemical properties are given below:

**1. Neutralization:**

Acids react with bases to form water. This reaction is called **Neutralization.**

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$$

**2. Reaction with Metal Oxides and Hydroxides (Bases):**

Metal oxide and hydroxide react with acid to form salt and water like **neutralization.**

$$FeO_{(s)} + H_2SO_{4(aq)} \longrightarrow FeSO_{4(aq)} + H_2O$$

$$Fe(OH)_{3(s)} + 3HCl_{(aq)} \longrightarrow FeCl_{3(aq)} + 3H_2O_{(l)}$$

**3. Reaction with Metals:**

Dilute acid reacts with certain metals such as (Zn, Mg and Fe) to produce ($H_2$) gas for example, dilute Hydrochloric acid reacts with (Zn) metal to produce $H_2$ gas.

$$Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2\,(aq)} + H_{2\,(g)}$$

**4. Reaction with Carbonates and Bicarbonates:**

Acids react with carbonate and bicarbonate salts to produce $CO_2$ gas.

$$Na_2CO_{3\,(s)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + H_2O_{\,(l)} + CO_{2\,(g)}$$

$$NaHCO_{3(s)} + HCl_{(aq)} \longrightarrow NaCl_{\,(aq)} + H_2O_{(l)} + CO_{2\,(g)}$$

## PHYSICAL PROPERTIES OF BASES:

1. Bases have bitter taste and have slippery or soapy touch.
2. Bases turn red litmus to blue.
3. Colourless phenolphthalein changes into red or pink in bases.
4. Methyl orange changes its colour from orange to yellow in bases.
5. Bases are electrolytes (their aqueous solutions conduct electricity).
6. Concentrated bases destroy fabrics, skin and human and plant tissues, etc.

**ALKALI:** ***Water soluble bases are also called Alkalis (NaOH, KOH)***

## DISSOCIATION OF ACIDS AND BASES

### STRENGTH OF ACID AND BASE:

The strength of an acid and base depends on dissociation into ions, higher the power of dissociation (ionization), greater will be the strength and vice-versa.

### STRONG ACID: (Strong Electrolyte)

An acid, which ionizes (dissociates) completely into ions, that means it produces large number of hydrogen ions ($H^+$) in aqueous solution is called **strong acid**. They are also called **strong electrolytes.**

**Example:** HCl, $HNO_3$ and $H_2SO_4$ are the most common examples of strong acids because they ionize completely in water. They are also known as ***<u>mineral acids.</u>***

### WEAK ACID: (Weak Electrolyte)

An acid, which ionizes partially into ions, that means it produces very small number of ions ($H^+$) in aqueous solution, is called **weak acid**. They are also called weak electrolytes.

**Example:** $H_2CO_3$ (Carbonic acid), $CH_3COOH$ (Acetic acid), HCOOH (Formic acid) and $(COOH)_2\,2H_2O$ (Oxalic acid).

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## STRONG BASE: (Strong Electrolyte)

A base, which dissociates (ionizes) completely into ions, that means it produces large number of hydroxyl ions ($OH^-$) in aqueous solution, is called strong base.

**Example:** NaOH, KOH, $Ca(OH)_2$ are the best examples of strong bases. They are also called strong electrolytes.

## WEAK BASE: (weak Electrolyte)

A base, which ionizes partially into ions, that means it produces ... small number of Hydroxyl ($OH^-$) ions in aqueous solution, is called weak base.

**Example:** $NH_4OH$, $Al(OH)_3$, $Cu(OH)_2$ are few weak bases. They are also called weak electrolytes.

# DIFFERENT CONCEPTS OF ACIDS AND BASES

## 1) ARRHENIUS THEORY:

In 1887 a Swedish chemist *Svante-Arrhenius,* gave the following definitions of acids and bases.

*"A substance which produces ($H^+$) ions in aqueous solution is called acid."*

**Example:**

$$HCl_{(aq)} \rightleftharpoons H^+_{(aq)} + Cl^-_{(aq)}$$

*"A substance which produces Hydroxide ($\bar{O}H$) ions in aqueous solution is called base."*

**Example:**

$$NaOH \xrightleftharpoons{H_2O} Na^+ + OH^-$$

## 2) LOWRY AND BRONSTED THEORY:

This theory was proposed by the English Chemist *Lowry* and Danish Chemist *Bronsted* in *1923.*

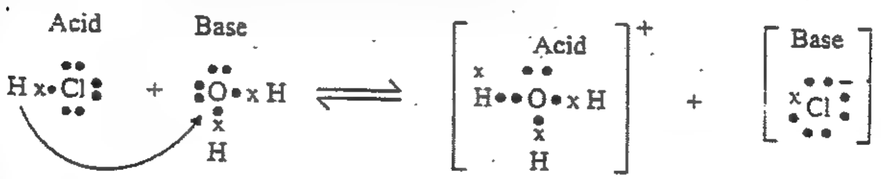
*An acid is a substance having a tendency to donate one or more protons and base is a substance having a tendency to accept protons.*

**Bronsted-Lowry acid : A substance that can donate ($H^+$) or proton.**

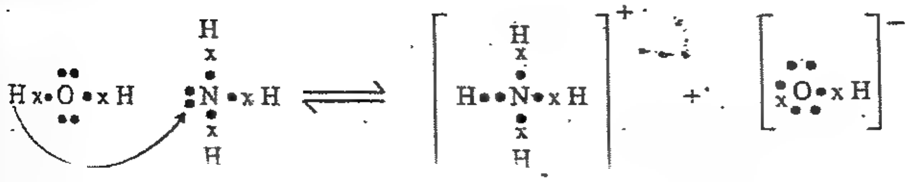
**Bronsted-Lowry base : A substance that can accept ($H^+$) or proton.**

## EXPLANATION:

Hydrochloric acid (HCl) and hydronium (oxonium) ion $[H_3O^+]$ are proton donors and act as *Bronsted-Lowry Acids,* whereas ($H_2O$) and Ammonia ($NH_3$) are proton acceptors and act as *Bronsted-Lowry Bases.*




Proton donor (Acid)    Proton acceptor (Base)    Proton donor (Acid)    Proton acceptor (Base)



Proton donor (Acid) — Proton acceptor (Base) — Proton donor (Acid) — Proton acceptor (Base)

## 3) LEWIS THEORY:

### Electron Based Explanation of Acids and Bases:

In *1923, G. N. Lewis* proposed a more general concept of acids and bases. According to Lewis theory:

- ***"An acid is any species (molecule or ion) which can accept a pair of electrons, and base is any species (molecule or ion) which can donate a pair of electrons."***

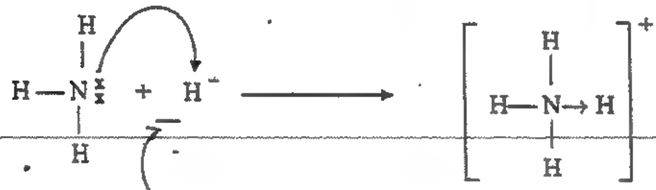
An acid-base reaction, in which electron pair donor is base and electron-pair acceptor, is acid. (They form a co-ordinate covalent bond).

*Lewis Acid* : ***An electron pair acceptor.***

*Lewis Base* : ***An electron pair donor.***

### EXPLANATION:

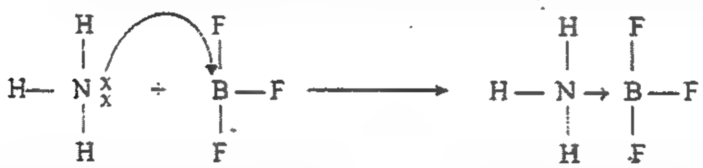
When Ammonia ($NH_3$) reacts with proton ($H^+$) to form ammonium ion ($NH_4^+$), in which the Nitrogen of ($NH_3$) donates a pair of electrons whereas the ($H^+$) accepts that pair of electrons for bond formation, this is shown by curved arrow.



Co-ordinate Covalent Bond

Electron pair donor *(Lewis base)* — Electron pair acceptor *(Lewis acid)* — Co-ordinate covalent bond

Another example is provided by the reaction of Ammonia ($NH_3$) with Boron tri fluoride ($BF_3$), in which Nitrogen of ($NH_3$) donates an electron pair and B of $BF_3$, which lacks a pair of electrons to complete its outer most shell (octet), accepts that pair of electrons and forms a co-ordinate covalent bond.



(Lewis base) — (Lewis acid) — Acid base product

Note: The bond between 'N' and 'B' is Co-ordinate Covalent Bond.

## SALT

***An ionic compound which is produced by neutralization of acid and base containing positive and negative ions is called salt.***

In other words, an ionic compound which is produced by the combination of positive and negative ions which come from base and acid respectively is also called salt.

**Example:** Potassium hydroxide neutralizes Nitric acid to form Potassium nitrate (Salt) and water.

$$KOH + HNO_3 \longrightarrow KNO_3 + H_2O$$

## TYPES OF SALTS:

On the basis of their chemical nature, salts can be divided into the following:

1) Normal Salts 2) Acidic Salts 3) Basic Salts

### 1. Normal Salt (Neutral Salt):

A salt which is formed by the complete neutralization of an acid by a base is called normal salts.

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

**Example: $NaCl$, $NaNO_3$, $K_2SO_4$, $MgSO_4$, etc. are normal salts.**

### 2. Acidic Salt (Acid Salt):

A salt which is formed by the **partial or incomplete neutralization** of an acid by a base is called acidic salt. (It has hydrogen ($H^+$) ion).

$$KOH + H_2CO_3 \longrightarrow KHCO_3 + H_2O$$

**Example: $NaHSO_4$, $KHCO_3$, $NaHCO_3$ etc. are acidic salts.**

### 3. Basic Salt (Base Salt):

A salt which is formed by the **partial or incomplete neutralization** of a base by an acid is called basic salt. (It has Hydroxide $OH^-$ ion).

$$Mg(OH)_2 + HCl \longrightarrow Mg(OH)Cl + H_2O.$$

**Example:** **$Mg(OH)Cl$, $Zn(OH)Cl$, etc. are basic salts.**

## DOUBLE SALTS:

The crystalline compound which is obtained, when two specific salts are crystallized together is known as double salt. It has some water of crystallization.

### Characteristics of Double Salt:

i) It has a definite chemical composition.

ii) It contains definite number of water molecules (water of crystallization).

**Examples:**

| | |
|---|---|
| Potash Alum | $K_2SO_4 . Al_2(SO_4)_3 . 24H_2O$ |
| Chrome Alum | $K_2SO_4 . Cr_2(SO_4)_3 . 24H_2O$ |
| Carnallite | $KCl . MgCl_2 . 6H_2O$ |
| Mohr's Salt | $FeSO_4 . (NH_4)_2SO_4 . 6H_2O$ |

## INDUSTRIAL PREPARATION OF SODIUM CARBONATE ($Na_2CO_3$)

Washing soda is commercially prepared by Ammonia-Solvey process or ammonia soda process.

**RAW MATERIALS:** The raw materials are:

1. Lime stone ($CaCO_3$)　　2. Sodium Chloride (NaCl)
3. Ammonium Chloride ($NH_4Cl$)　4. Carbon dioxide ($CO_2$)

**The industrial process involves the following steps:**

**STEP 1:** Lime stone [$CaCO_3$] is heated to yield calcium oxide (quicklime CaO) and the $CO_2$ gas.

$$CaCO_{3(s)} \xrightarrow{\Delta} CaO_{(s)} + CO_{2(g)}$$

**STEP 2:** This ($CO_2$) is passed into aqueous solution of ammonia, and the ammonium bicarbonate is produced.

$$NH_{3(g)} + CO_{2(g)} + H_2O_{(l)} \longrightarrow NH_4HCO_{3(aq)}$$

**STEP 3:** Ammonium bicarbonate (**$NH_4HCO_3$**) reacts with aqueous cold solution of sodium chloride (**NaCl**) at **15°C**, called **Brine** to yield, sodium bicarbonate (**$NaHCO_3$**), which is not soluble at low temperature (15°C) and this precipitates out.

$$NaCl_{(aq)} + NH_4^+HCO_{3(aq)}^- \xrightarrow{\text{At 15°C brine}} NH_4Cl_{(aq)} + NaHCO_{3(s)}$$

**STEP 4:** Sodium bicarbonate ($NaHCO_3$) on heating yields sodium carbonate ($Na_2CO_3$).

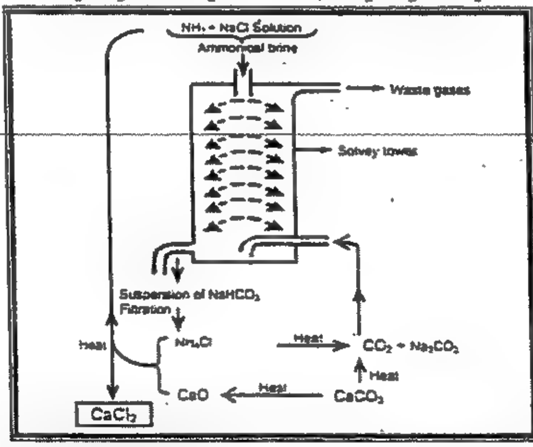
$$2NaHCO_{3(s)} \xrightarrow{\Delta H} Na_2CO_{3(s)} + H_2O_{(l)} + CO_{2(g)}$$

**STEP 5:** The ammonia ($NH_3$) which is used as a raw material in $2^{nd}$ step, is recovered by reacting (CaO) with $NH_4Cl$.

$$2NH_4Cl_{(aq)} + CaO_{(s)} \longrightarrow 2NH_{3(g)} + CaCl_{2(aq)} + H_2O_{(l)}$$

**STEP 6:** Anhydrous sodium carbonate ($Na_3CO_3$) is known as **soda-ash** and sodium carbonate decahydrate (**$Na_2CO_3 . 10H_2O$**) is commonly known as **washing soda.**

$$Na_2CO_3 + 10H_2O \xrightarrow{heat} Na_2CO_3 . 10H_2O$$




## USES OF SODIUM BICARBONATE or BAKING SODA ($NaHCO_3$):

1. Sodium Hydrogen carbonate (sodium bicarbonate) is used as baking powder.
2. It is used in the preparation of effervescent drinks and fruit salts.
3. It is used in medicines to remove acidity in stomach as anti-acid (antacid).
4. It is used in fire extinguishers.

## USES OF SODIUM CARBONATE ($Na_2CO_3$):

1. It is used as cleaning agent in soap and detergent.
2. It is used to make ordinary glass which is used to make bottles.
3. It is used in manufacturing of papers, cement and paints.
4. Hard water is changed into soft water by adding sodium carbonate ($Na_2CO_3$) which forms insoluble Calcium Carbonate ($CaCO_3$) and Magnesium Carbonate ($MgCO_3$).

$$CaCl_{2(aq)} + Na_2CO_{3(aq)} \longrightarrow CaCO_{3(s)} + 2NaCl_{(aq)}$$

$$MgCl_{2(aq)} + Na_2CO_{3(aq)} \longrightarrow MgCO_{3(s)} + 2NaCl_{(aq)}$$

## COPPER SULPHATE ($CuSO_4.5H_2O$):

Copper sulphate or Cupric sulphate which is also known as ***Blue Vitriol or Blue Stone*** may be prepared by two methods which are given below:

It is prepared by the reaction of Copper scraps with dilute Sulphuric acid in the presence of air.

$$2Cu_{(s)} + 2H_2SO_{4\,(aq)} + O_{2(g)} \longrightarrow 2CuSO_{4\,(aq)} + 2H_2O_{(l)}$$

It is also be prepared by the reaction of CuO or $CuCO_3$ with dilute Sulphuric acid ($H_2SO_4$).

$$CuO_{(s)} + H_2SO_{4\,(dil)} \longrightarrow CuSO_{4\,(aq)} + H_2O_{(l)}$$

$$CuCO_{3(s)} + H_2SO_{4\,(dil)} \longrightarrow CuSO_{4\,(aq)} + CO_{2(g)} + H_2O_{(l)}$$

### USES OF COPPER SULPHATE:

1. Copper sulphate is used in green paint and varnish industry.
2. As germicide, insecticide, preservative for wood and paper pulp.
3. In Calico printing, for making synthetic rubber and copper salts (Scheels).
4. A mixture of Copper sulphate and milk of lime is used to kill fungus and moulds.
5. In textiles (as mordant), tanning, electric batteries, hair dyes and in electroplating.

## MAGNESIUM SULPHATE ($MgSO_4.7H_2O$) (EPSOM SALT):

It is prepared by the action of $H_2SO_4$ and Magnesite or Dolomite:

(i) $\underset{\text{Magnesite}}{MgCO_3} + H_2SO_4 \longrightarrow MgSO_4 + H_2O + CO_{2(g)}$

(ii) $\underset{\text{Dolomite}}{MgCO_3.CaCO_3} + 2H_2SO_4 \longrightarrow MgSO_4 + CaSO_4 + 2H_2O + 2CO_{2(g)}$

### USES OF MAGNESIUM SULPHATE:

1. It is used as filler in paper industry.
2. It is used in making fire proof fabrics.
3. It is used in dyeing and tanning processes.
4. It is used as a mild purgative (antacid) in medicines.
5. It is used in the manufacture of ceramics, glazed tiles and match boxes.

## PREPARATION OF POTASH ALUM:

$K_2SO_4 . Al_2(SO_4)_3 . 24H_2O$ (a double salt) can be prepared by adding equal molar solutions of Potassium sulphate $K_2SO_4$ and Aluminium sulphate $Al_2(SO_4)_3$ by dissolving in water. This solution is crystallized to form Potash Alum.

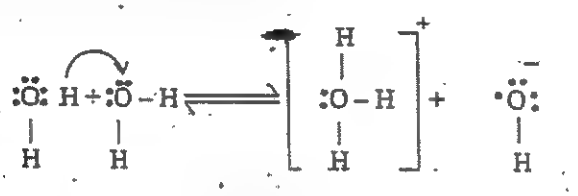
## USES OF POTASH ALUM:

1. Alum is used in sizing paper.
2. Alum is used in purifying water.
3. Alum is used in the tanning of leather.
4. Alum is used in dyeing as mordant (to fix insoluble dye to fibre).
5. Alum is used as antiseptic and a mouth wash as well as in medicines.

## DISSOCIATION OF WATER:

Water acts as an acid as well as a base. A substance like water which can behave as both an acid and a base is said to be an **amphoteric substance.**

On adding acid or base to water, it ionizes. A proton from water molecules is transferred to another water molecule leaving behind ($OH^-$) hydroxyl (hydroxide) ion and forming ($H_3O^+$) oxonium (hydronium) ion.



Hydronium ion Hydroxyl ion

## IONIC PRODUCT OF WATER:

During neutralization, salt and water molecules are formed and the concentrations of Hydrogen $(H)^-$ ions and Hydroxide ions ($OH^-$) remain almost same.

$$H_2O \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)}$$

$$K_c = \frac{[H^+]\,[OH^-]}{[H_2O]}$$

$K_c$ is the equilibrium constant. It shows that a very small fraction of water molecules are ionized. That means water remains mostly unchanged. Therefore,

$$K_c\,[H_2O] = K_w = [H^+]\,[OH^-]$$

Constant ($K_w$) is called **ionic product constant** which is the product of molar concentration of ($H^+$) ion and ($OH^-$) ions at 25°C is found to be $1 \times 10^{-14}$ mole$^2$/dm$^6$ ($M^2$).

$$[H^+] = 1 \times 10^{-7}\,M \text{ and } [OH^-] = 1 \times 10^{-7}\,M$$

$$K_w = (1 \times 10^{-7}) \times (1 \times 10^{-7}) = 1 \times 10^{-14}\,M^2$$

***Above equation shows that $[H^+] = [OH^-]$ that is why Water is Neutral.***

***If $[H^+]$ ion concentration increases in aqueous solution, then the solution becomes acidic. If ($OH^-$) ion concentration increases in aqueous solution, then the solution becomes basic.***

## pH:

The Danish chemists *Sorensen*, proposed the measurement of the power of hydrogen ions in aqueous solution. pH means power of hydrogen ($H^+$) ions.

***The negative logarithm of the concentration of Hydrogen ion ($H^+$) in aqueous solution is called pH.***

**Mathematically:**

$$pH = -\log [H^+]$$

Any neutral solution like water in which $[H^+]$ ion concentration is $1 \times 10^{-7}$ M so,

$$pH = -\log [H^+]$$
$$= -\log [10^{-7}]$$
$$= -(-7) \log 10$$
$$= 7 \times \log 10 \qquad \therefore (\log 10 = 1)$$
$$= 7 \times 1$$
$$\boxed{pH = 7} \text{ Answer}$$

## pOH:

***The negative logarithm of the concentration of hydroxyl ion ($OH^-$) in aqueous solution is called pOH.***

$$pOH = -\log [OH^-]$$

**The sum of pH and pOH of water or any solution is equal to 14.**

**i.e.** $\quad pH + pOH = 14$

## THE MEASUREMENT OF pH:

Following are the methods used to measure the pH of a solution:

(1) By acid base indicator (2) By pH meter (3) By pH paper

pH paper method is the most common in school laboratories. pH paper strips prepared by treating paper with several different indicators can be used to estimate pH. These strips are pH papers.

pH can be estimated by dipping the pH paper in a given solution, then by matching the change of colour with given key colours with corresponding known values.

## THE IMPORTANCE OF pH:

The value of pH in different solutions gives information through which necessary steps to control the problems are possible. Water treatment, soil conditioning, swimming pool management, corrosion control, food processing, electroplating and field of Biology, etc. are common areas where pH values play important role.

**Example:** The pH of Normal human blood is 7.35 to 7.45. The pH value of various body fluids is very important for a doctor in diagnosing and treating many illnesses. e.g. if pH of blood decreases upto 7. patient may go into *coma*. If pH of blood becomes less than 6, death may occur. If pH rises as high as 7.7 or 7.8 it causes **diabetes**, excessive *vomiting* and **diarrhoea**.

## PREPARATION OF STANDARD SOLUTION (KNOWN CONCENTRATION)

Molar solution can be prepared by dissolving one mole of solute into 1 $dm^3$ (1 litre) of solution. Consider the example of (NaOH) 23 + 16 + 1 = 40g Sodium hydroxide dissolved in some amount of water in measuring flask to prepare 1 $dm^3$ of solution by adding water. Solution of 1M NaOH will be prepared. This solution is called standard solution.

## STANDARD SOLUTION:

A solution of known concentration (molarity or molality) is called Standard Solution.

## UNSTANDARD SOLUTION:

A solution of unknown concentration (molarity or molality) is called Unstandard Solution.

## TITRATION:

***A process in which an unstandard solution becomes standardized by using a standard solution is called titration.***

In other words, the volumetric analysis through chemical process in which by using standard solution, the concentration of another solution is determined. This method is called Titration.

## ACID-BASE TITRATION:

Standard solution of acid is used to standardize base (unknown concentration) by acid base titration or reverse method is possible, to standardize acid.

## STEPS FOR CARRYING OUT TITRATION:

Wash all the apparatus with water and then rinse the burette with base and pipette with acid including conical flask. Fill the burette with NaOH upto zero mark. The solution in the burette is called **"Titre"**.

Pipette out 10ml ($cm^3$) of HCl in a conical flask and add one or two drops of phenolphthalein indicator. The solution in titration flask is called **"Titrant"**.

Add slowly the NaOH solution from the burette into flask with constant shaking unless the lightest pink colour is obtained. Record the final reading (lower meniscus).

This is called End point. Repeat the process at least three times to get concordant reading (two same differences at least in three readings).

After completing the observation we use the following formula to determine the Molarity of acid or base.

$$\frac{M_1V_1}{n_1} = \frac{M_2V_2}{n_2} \quad OR \quad \frac{M_aV_a}{n_a} = \frac{M_bV_b}{n_b}$$

Let

| | | |
|---|---|---|
| $M_a$ : Molarity of Acid | | |
| $V_a$ : Volume of Acid | (10ml) | |
| $n_a$ : No of mole of acid | (obtained from balanced equation) | |
| $n_b$ : No of moles of Base | (obtained from balanced equation) | |
| $V_b$ : Volume of base | (burette reading) | |
| $M_b$ : Molarity of base | | |

## NEUTRALIZATION:

*The process in which an acid reacts with a base to form salt and water is called neutralization reaction.*

A common example is the reaction between HCl and NaOH.

$$HCl_{(aq)} + NaOH_{(aq)} \rightleftharpoons NaCl_{(aq)} + H_2O_{(l)}$$

The Hydrogen ion ($H^+$) which is responsible for acidic properties reacts with the Hydroxide ion ($OH^-$), which is responsible for the basic properties, producing neutral water (H–OH). Neutralization may be expressed as:

Neutralization is an example of **double displacement** as well as **exothermic** reaction.

e.g. $HCl_{(aq)} + NaOH_{(aq)} \rightleftharpoons NaCl_{(aq)} + H_2O_{(l)} \quad \Delta H = -57.3 KJ/mol$

## MONO AND POLY ACIDS AND BASES:

### Basicity of Acid:

*"The number of replaceable or ionizable Hydrogen ($H^+$) ions from one mole (molecule) of an acid is called Basicity of acid."*

*Mono Basic Acids*: The common acids like (**HCl**), (**$HNO_3$**) and (**$CH_3COOH$**) contain 1 mole of Hydrogen ($H^+$) ion per mole is called *mono-basic acids* or *mono-protic acids.*

$$\text{e.g.}\quad H^{+\delta}-Cl^{-\delta}{}_{(aq)} + H^{+\delta}-OH^{-\delta}{}_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + Cl^-{}_{(aq)}$$

*Di Basic Acids*: Sulphuric acid (**$H_2SO_4$**) contains 2 moles of Hydrogen ($H^+$) ions per mole is called *dibasic* or *diprotic acid.* Sulphuric acid ($H_2SO_4$) dissociates in two steps:

$$H_2SO_{4\,(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + HSO_4^-{}_{(aq)}$$

$$HSO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + SO_4^{2-}{}_{(aq)}$$

*Tri Basic Acids* : The acid like Phosphoric acid (**$H_3PO_4$**), which contains 3 moles of Hydrogen ($H^+$) ions per mole is called *tri basic acid* or *tri-protic acid.*

$$H_3PO_{4(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + H_2PO_4^{1-}{}_{(aq)}$$

$$H_2PO_4^{1-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + HPO_4^{2-}{}_{(aq)}$$

$$HPO_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + PO_4^{3-}{}_{(aq)}$$

Acids that contain two or more acidic hydrogen per mole are called *poly-basic acids*, or more commonly *poly-protic acids.*

### Acidity of Bases:

*"The number of replaceable or ionizable hydroxide ($OH^-$) ions from a mole (molecule) of a base is called Acidity of base."*

*Mono Acid Bases*: **NaOH, KOH, $NH_4OH$** can produce 1 mole of ($OH^-$) ions per mole of base are called *mono-acid bases.*

*Di Acid Bases*: **$Ca(OH)_2$** and **$Mg(OH)_2$** can produce 2 moles of ($OH^-$) ions per mole of base are called *di-acid bases.*

*Tri Acid Bases*: **$Al(OH)_3$** and **$Fe(OH)_3$** can produce 3 moles of ($OH^-$) ions per mole of base are called *tri-acid bases.*

Bases that contain two or more hydroxide ($OH^-$) ions per molecule are called *poly-acid bases.*

# EXERCISE

## 1. Fill in the Blanks.

i) The formula of baking soda is **$NaHCO_3$.**
ii) The formula of Epsom salt is **$MgSO_4\ 7H_2O$.**
iii) $K_2SO_4Al_2(SO_4)_3.24\ H_2O$ is the formula of **Potash Alum.**

v) The molarity of solution is denoted by **M.**
vi) A solution whose strength is known is called **Standard Solution.**
vii) If $H^-$ ion concentration of a solution is $1 \times 10^{-14}$ M, the solution is **Strong basic.**
viii) If the $OH^-$ ion concentration of a solution is $1 \times 10^{-10}$ M solution is **Strong acidic.**
ix) **Titration** is the process by which we can determine the concentration of unknown solution with the help of standard solution.
x) The solution whose $H^+$ ion concentration is $1 \times 10^{-4}$ M, then its pH is **4.**
xi) The solution whose pH is 6, then its $H^+$ ion concentration is **$1 \times 10^{-6}$.**
xii) The volume of a pipette is generally **10** ml or $cm^3$.
xiii) Molarity is defined as number of moles per **litre or $dm^3$ of solution.**

## 2. Tick the Correct Answer.

i) The substances whose aqueous solutions change the blue litmus to red.
a) Acids b) Bases c) Neutral d) Salts

ii) The substances having a tendency to lose one or more protons are called:
a) Acids b) Bases c) Neutral d) Salts

iii) The substances which donate the pair of electrons for bond formation are known as:
a) Acids b) Bases c) Neutral d) Salts

iv) When equivalent quantities of acid and base are mixed, salt and water are formed, the reaction is termed as:
a) Hydration b) Hydrolysis c) Neutralization d) none of these

v) The acids which contain one acidic hydrogen are called:
a) Mono-protic b) Di-protic c) Neutralization d) Poly protic

vi) The number of acidic hydrogen atoms present in a molecule of an acid is called:
a) Acidity b) Basicity c) Neutral d) Hydrolysis

vii) The number of replaceable $[OH^-]$ ions present in a molecule of base is called:
a) Acidity b) Basicity c) Neutral d) Hydrolysis

viii) An acid that produces large number of $(H^-)$ ions in aqueous solution is called:
a) Strong base b) Weak base c) Strong Acid d) Weak acid

ix) An ionic compound that is formed when an acid neutralizes a base is called:
a) Acid b) Base c) Neutral d) Salt

x) Salts that are formed by the reaction of strong acid with weak base are:
a) Neutral b) Acidic c) Basic d) Normal

xi) Salts that are formed by the reaction of weak acid with strong base are:
a) Acidic b) Basic c) Neutral d) Normal

xii) Alums are:
a) Single salts b) Double salts c) Triple salts d) Normal salts

xiii) The formula of Washing soda is:
a) $Na_2CO_3$ b) $Na_2CO_3 . 6H_2O$ c) $Na_2CO_3.10H_2O$ d) $NaHCO_3$

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| i | a | ii | a | iii | b | iv | c | v | a |
| vi | b | vii | a | viii | c | ix | d | x | b |
| xi | b | xii | b | xiii | c | | | | |

**3. Write answer of the following questions:**

**i) What is Arrhenius theory of acids and bases? Why is the Arrhenius theory not satisfactory for acids and bases?**

Ans. **ARRHENIUS THEORY:**

A Swedish chemist ***Svante-Arrhenius*** in ***1887*** gave definitions of acids and bases.

***"A substance which produces Hydrogen ($H^+$) ions in aqueous solution is called an acid."***

$$HCl_{(aq)} \xrightleftharpoons{H_2O} \overset{+}{H}_{(aq)} + \overset{-}{Cl}_{(aq)}$$

***"A substance which produces Hydroxide ($OH^-$) ions in aqueous solution is called base."***

**Example:**

$$NaOH_{(aq)} \xrightleftharpoons{H_2O} \overset{+}{Na}_{(aq)} + \overset{-}{OH}_{(aq)}$$

**Why did Arrhenius Theory Failed:**

Arrhenius definition of acids and bases are limited in that, they apply only to water (aqueous) solutions and it does not account for the acidity of $NH_3$, it does not contain ($OH^-$) group. Few acid molecules also do not contain ($H^+$) ions.

**ii) What is Lewis theory of acids and bases?**

ANSWER ON PAGE # 6

**iii) List the main general properties of acids and bases.**

**PHYSICAL PROPERTIES OF ACIDS:**

ANSWER ON PAGE # 3

**CHEMICAL PROPERTIES OF ACIDS:**

ANSWER ON PAGE # 4

**PHYSICAL PROPERTIES OF BASES:**

ANSWER ON PAGE # 4



**iv) Write the formulae of strong acids and weak acids.**

Ans. **DISSOCIATION OF ACIDS AND BASES**

ANSWER ON PAGE # 4 & 5

**v) Sulphuric acid ($H_2SO_4$) is strong acid while, ($HSO_4^-$) is a weak acid? Account for the difference in strength?**

Ans. Sulphuric acid is strong acid because its molecule produces two hydrogen ($H^+$) ions while $HSO_4^-$ acts as weak acid because it produces only one $H^+$ ion.

**vi) What is salt? Give four examples of salts.**

Ans. **SALT**

An ionic compound produced as a result of neutralization between acids and a base having positive and negative ions is called salt.

**Example:** Potassium hydroxide neutralizes Nitric acid to form Potassium nitrate as Salt and water.

$$KOH + HNO_3 \longrightarrow KNO_3 + H_2O$$

**GROUPS (TYPES) OF SALTS:**

ANSWER ON PAGE # 7

vii) **Give an example each of mono-protic acid, di-protic acid and tri-protic acid.**

ANSWER ON PAGE # 13

viii) **Identify the following as a weak or strong acids or bases.**

(a) $NH_3$ (b) $H_3PO_4$ (c) LiOH (d) HCOOH (Formic acid)

(e) $H_2SO_4$ (f) $H_2CO_3$ (g) $Al(OH)_3$ (h) $Ba(OH)_2$

Ans.

| Strong Acid | Weak Acid | Strong Base | Weak Base |
|---|---|---|---|
| (e) $H_2SO_4$ | (b) $H_3PO_4$ | (c) LiOH | (a) $NH_3$ |
| | (d) HCOOH | (h) $Ba(OH)_2$ | (g) $Al(OH)_3$ |
| | (f) $H_2CO_3$ | | |

ix) **Define molarity? What is molar solution?**

Ans. **Molarity (M):**

**"The number of moles of solute dissolved in $1dm^3$ (1 litre) of a solution."**

$$\text{Molarity (M)} = \frac{\text{Moles of Solute}}{\text{Volume of Solution}(dm^3)}$$

*OR*

$$\text{Molarity} = \frac{\text{Mass of Solute}}{\text{Molar Mass of Solute x Volume of Solution}(dm^3)}$$

Molar solution means, 1 mole of solute dissolved in 1 litre (1 $dm^3$) of solution.

x) **Define pH? Explain why a neutral solution is said to have a pH of seven.**

Ans. **pH SCALE:**

The Danish chemist Sorensen proposed that only the number in the exponent be used to express the acidity called pH from the French (Puissance d, Hydrogen = potential of Hydrogen). On this scale, a concentration of ($1 \times 10^{-7}$) moles of $H_3O^+$ ions per liter of solution becomes a pH of 7. Similarly a concentration $1 \times 10^{-10}$ M becomes a pH of 10 and so on.

**pH SCALE:**

"The negative logarithm of the concentration of Hydrogen ion $[H^+]$ is called pH scale."

**Mathematically:**

$$pH = -\log [H^+]$$

Any neutral solution like water in which $[H^+]$ ion concentration is $1 \times 10^{-7}$ M.

$$\begin{aligned} pH &= -\log [H^+] \\ &= -\log [10^{-7}] \\ &= -(-7) \log 10 \\ &= 7 \log 10 \\ &= 7 \times 1 \end{aligned}$$

$\boxed{pH = 7}$ Answer

Similarly the pOH is also 7, i.e. the value of pH = 7 and pOH = 7, thus *solution is Neutral.*

The sum of pH and pOH of any solution is always equal to 14.

i.e. $\quad pH - pOH = 14$

$\quad\quad 7 + 7 = 14$

**xi) Calculate the pH of the following solutions.**

**(a) 0.001 M of HCl**

**Solution**

$$0.001\ M = \frac{1}{1000} = \frac{1}{10^3} = 10^{-3} M$$

**Formula**

$$\begin{aligned} pH &= -\log [H^+] \\ &= -\log [10^{-3}] \\ &= -(-3) \log 10 \quad \therefore (\log 10 = 1) \\ &= -(-3) \times 1 \\ &= -(-3) \end{aligned}$$

$pH = 3$

$\boxed{pH = 3}$ **Ans.**

**xii) Calculate ($H^+$) ion concentration of solutions, whose**

**(a) pH = 5.2 $\quad$ (b) pH = 9.63**

Ans. (a) pH = 5.2

Concentration = ?

**Solution:**

**Formula:**

$\log H^+ = -pH$

$\log H^+ = -5.2$

$\log H^+ = (0.8 - 6)$

Taking Antilog on both sides

$H^+ = 6.310 \times 10^{-6} M$

$\boxed{H^+ = 6.3 \times 10^{-6}\ mole/dm^3}$ **Ans.**

Ans. (b) pH = 9.63

Concentration = ?

**Solution:**

**Formula:**

$\log H^+ = -pH$

By putting values

$\log H^+ = -9.63$

$\log H^+ = (0.37 - 10)$

Taking Antilog on both sides

$H^+ = 2.344 \times 10^{-10} M$

$\boxed{H^+ = 2.344 \times 10^{-10}\ mole/dm^3}$ **Ans.**

**xiii) Fill in the word acidic, basic or neutral for the following solutions:**

(a) pH = 7 <u>Neutral</u>

(b) pH > 7 <u>Basic</u>

(c) pH < 7 <u>Acidic</u>

**xiv) The pOH of a solution is 9.40? Calculate the ($H^+$) ion concentration.**

Ans. pOH = 9.40

Required

$H^+$ concentration = ?

**Solution:**

$$pH + pOH = 14$$
$$pH + 9.4 = 14$$
$$pH = 14 - 9.4$$
$$pH = 4.6$$
$$\log H^+ = -pH$$
$$= -4.6$$
$$\log H^+ = (0.4 - 5)$$

Taking Antilog on both sides

$\boxed{H^+ = 2.512 \times 10^{-5}\ mol/dm^3}$ Ans.



**xv) Describe clearly how a solution of HCl could be titrated with a solution of NaOH?**

ANSWER ON PAGE # 12

**xvi) What volume of 0.5 M KOH solutions is needed to neutralize completely each of the following:**

| | |
|---|---|
| **(a) 10.0 ml of 0.3 M HCl solution (b) 10.0 ml of 0.2 M $H_2SO_4$ solution (a) Data:**<br>Molarity of KOH = $M_1$ = 0.5 M<br>Molarity of HCl = $M_2$ = 0.3 M<br>Volume of HCl = $V_2$ = 10 ml<br>Volume of KOH = $V_1$ = ?<br>**Solution:**<br>$M_1V_1 = M_2V_2$<br>By putting values<br>$= \frac{0.3 \times 10}{0.5}$<br>$V_1 = 6$ ml<br>$\boxed{\text{Volume of KOH} = 6\ ml}$ Ans. | **(b) Data:**<br>Molarity of KOH = $M_1$ = 0.5 M<br>Molarity of $H_2SO_4$ = $M_2$ = 0.2 M<br>Volume of $H_2SO_4$ = $V_2$ = 10 ml<br>Volume of KOH = $V_1$ = ?<br>**Solution:**<br>$M_1V_1 = M_2V_2$<br>By putting values<br>$= \frac{0.2 \times 10}{0.5}$<br>$V_1 = 4$ ml<br>$\boxed{\text{Volume of KOH} = 4\ ml}$ Ans. |

SESSION
2016-2017

# CLASS-IX

# CHEMISTRY

## Chapter # 10

## CHEMICAL ENERGETICS

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# CHEMICAL ENERGETICS 10

## THERMOCHEMISTRY:

*The branch of chemistry which deals with the study of heat changes in chemical*

*(OR)*

*The branch of chemistry which deals with the study of chemical reactions in which heat is evolved or absorbed is called thermochemistry.*

## THERMOCHEMICAL REACTIONS (THERMO REACTIONS):

*The chemical reactions during which material changes are accompanied with change in heat energy are called thermochemical reactions*

In other words, during the conversion of reactants to products along with evolution or absorption of energy is called thermo reactions.

## TYPES OF THERMOCHEMICAL REACTIONS:

There are two types of thermochemical reactions:

1. Exothermic Reactions     2. Endothermic reactions

## (1) EXOTHERMIC REACTION:

*When heat energy is evolved (released) or given out during a chemical change or reaction is called exothermic reaction.*

*Explanation:*

During exothermic reaction, heat energy is released from system to surroundings so total energy of the system decreases. It is because total energy of the reactants is greater than total energy of products. EXO means outside and THERM means heat.

The change of heat energy is represented by **ΔH** with negative sign in equations. The general representation is:

$$\text{Reactants} \longrightarrow \text{Products} + \text{heat}$$

All combustion, single displacement and most of the addition reactions are the examples of exothermic reactions.

**Examples:**

### (i) COMBUSTION OF COAL (BURNING OF CARBON):

The combustion of coal in air is the example of exothermic reaction. 393.7 Kilo joule per mole of heat energy is released when 1 mole of coal reacts with 1 mole of $O_2$ to form 1 mole of $CO_2$.

$$C_{(s)} + O_{2\,(g)} \longrightarrow CO_{2\,(g)} \qquad \Delta H = -393.7\ KJ/mol$$

### (ii) FORMATION OF WATER FROM HYDROGEN AND OXYGEN:

The formation of water from Hydrogen and Oxygen is also an example of exothermic reaction. 286 Kilo joule per mole of heat energy is released. when 1 mole of $H_2$ reacts with half mole of $O_2$ to form 1 mole of $H_2O$.

$$H_{2\,(g)} + \frac{1}{2}O_{2\,(g)} \longrightarrow H_2O_{\,(l)} \qquad \Delta H = -286\ KJ/mol$$

### (iii) COMBUSTION OF METHANE (BURNING OF METHANE):

Burning of methane in presence of oxygen is another example of exothermic reaction When 1 mole of methane is burnt in 2 moles of $O_2$, then one mole of $CO_2$ and 2 moles of water are formed. During this reaction 890 Kilo joule per mole of heat energy is released.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(l)} \qquad \Delta H = -890\ KJ/mol$$

## (2) ENDOTHERMIC REACTION:

***When heat energy is absorbed (taken in) during a chemical change or reaction is called endothermic reaction.***

*Explanation:*

During endothermic reaction heat energy is absorbed from surroundings to system so total energy of the system increases. It is because total energy of the reactants is lesser than total energy of products. **ENDO** means inside while **THERM** means heat.

The change of heat energy is represented by $\Delta H$ with positive sign in equations.

The general representation is:

$$\text{Reactants} + \text{heat} \longrightarrow \text{Products}$$

**Decomposition** reactions are the example of endothermic reactions.

### Examples:

### (i) DECOMPOSITION OF WATER:

The decomposition of water into Hydrogen and Oxygen is an example of endothermic reaction. During the decomposition of 1mole of water, 1mole of Hydrogen gas and half mole of oxygen gas are formed when 286 Kilo joule per mole of heat energy is **absorbed**.

$$H_2O_{(l)} \longrightarrow H_{2(g)} + \frac{1}{2}O_{2(g)} \qquad \Delta H = +286\ KJ/mol$$

### (ii) FORMATION OF NITRIC OXIDE:

1mole of Nitric oxide (NO) is formed by combination of $\frac{1}{2}$ mole of $N_2$ and $\frac{1}{2}$ mole of $O_2$. This is the example of endothermic reaction. During this reaction 90 Kilo joules per mole heat energy is **absorbed**.

$$\frac{1}{2}N_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow NO_{(g)} \qquad \Delta H = +90\ KJ/mol$$

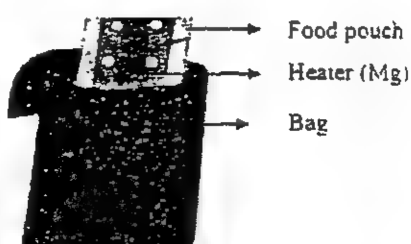
## USE OF EXOTHERMIC REACTIONS

### To make food warm:

In modern army, armed forces can be warmed their food without using stove or campfire. The pouch that contains the food is attached to flameless radiation heater. The heater contains chemicals that react with water to produce heat. When the pouch is placed in a bag and water is added, temperature of the food reaches upto 60°C within 15 minutes.

$$Mg_{(s)} + 2H_2O_{(l)} \longrightarrow Mg(OH)_{2(s)} + H_{2(g)} \qquad \Delta H = -3.53\ KJ/mol$$

The reaction of (Mg) with water is slow, because of the formation of film of Magnesium Oxide (MgO). The reaction of Mg with water is highly accelerated in the presence of iron (Fe) and common salt (NaCl). Thus, the flameless radiation heater contains a mixture of Mg (Magnesium), Fe (Iron) and NaCl (Sodium Chloride).



## Differences between Exothermic and Endothermic Reactions

| EXOTHERMIC REACTIONS | ENDOTHERMIC REACTIONS |
|---|---|
| The reaction in which heat energy is released is called Exothermic reaction. | The reaction in which heat energy is absorbed is called Endothermic reaction. |
| During this reaction, total energy of the system decreases. | During this reaction, total energy of the system increases. |
| **Exo** stands for outside while therm means heat. | **Endo** stands for inside while therm means heat. |
| It is denoted by $\Delta H$ with negative sign. | It is denoted by $\Delta H$ with positive sign. |
| The initial enthalpy (energy) of the reaction is greater than the final enthalpy of the reaction. | The initial enthalpy (energy) of the reaction is less than the final enthalpy of the reaction. |
| Combustion, neutralization, addition and single displacement reactions are the examples of exothermic reactions. | Decomposition reactions are the examples of endothermic reactions. |
| The general representation is<br>Reactants $\longrightarrow$ Products + heat | The general representation is<br>Reactants + heat $\longrightarrow$ Products |

### HEAT OF REACTION:

The amount of heat absorbed or evolved during a chemical reaction is called heat of reaction.

### HEAT CONTENTS OF A SUBSTANCE (ENTHALPY):

Every substance has internal energy which is called heat contents of that substance. Heat contents of a reaction are also called *Enthalpy*.

***The whole contents of a system (substance) are called enthalpy.***

It is denoted by (H).

### ENTHALPY OF REACTION:

***The heat evolved or absorbed at constant pressure is known as enthalpy of the reaction or enthalpy change.***

### Explanation:

In a chemical reaction, the reactants are converted into products and heat energy is either absorbed or evolved. This is because the heat contents of these respective substances are different. It means the *Enthalpy* of a Chemical Reaction is ***the difference between the heat contents of products ($H_2$) and reactants ($H_1$) of that reaction.***

$$\Delta H = H_2 - H_1$$

### Representation of Enthalpy:

The heat contents (enthalpy) of a substance are represented by "H" and the change in heat content during a chemical reaction is then represented by $\Delta H$. Here Greek letter $\Delta$ (delta) represents the change in the property.

## Enthalpy for Endothermic Reaction:

If enthalpy of products is greater than the enthalpy of reactants, then the sign of $\Delta H$ will be positive and over all reaction is endothermic and heat is absorbed.

$\Delta H = H_2 - H_1$ [$H_2 > H_1$ so $\Delta H$ is positive]

Where

$H_1$ : heat contents of reactants
$H_2$ : heat contents of products

**Examples:**

$$H_2O \longrightarrow H_2 + 1/2O_2 \qquad \Delta H = +286.0\ KJ/mol$$
$$CO_2 \longrightarrow C + O_2 \qquad \Delta H = +393.7\ KJ/mol$$
$$1/2\ N_2 + 1/2\ O_2 \longrightarrow NO \qquad \Delta H = +90.0\ KJ/mol$$

## Enthalpy for Exothermic Reaction:

If enthalpy of products is smaller than the enthalpy of reactants, then the sign of $\Delta H$ will be negative and overall reaction is exothermic and heat is evolved.

$\Delta H = H_2 - H_1$ [$H_2 < H_1$ so $\Delta H$ is negative]

$$H_2 + 1/2O_2 \longrightarrow H_2O \qquad \Delta H = -286.0\ KJ/mol$$
$$C + O_2 \longrightarrow CO_2 \qquad \Delta H = -393.7\ KJ/mol$$
$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O \qquad \Delta H = -890.4\ KJ/mol$$

## THE MEASUREMENT OF ENTHALPY

Exothermic and endothermic reactions can be detected by knowing the temperature of the reaction vessel before and after the reaction.

- A rise in temperature indicates an exothermic reaction.
- A fall in temperature indicates an endothermic reaction.
- Accurate value of $\Delta H$ can be determined by using *Calorimeter*.
- A calorimeter is basically an insulated container equipped with a thermometer and a stirrer.

### Procedure:

Reactants in calculated amounts are placed in the calorimeter. When the reaction proceeds, the heat energy evolved or absorbed. The temperature of the system before and after the chemical reaction is recorded. Knowing the temperature change, the mass of reactants present and the specific heat capacity of the reaction mixture, the value of $\Delta H$ can be calculated.

## NEUTRALIZATION

***The reaction in which an acid reacts with a base to form water is called Neutralization Reaction. In other words,*** **when an acid reacts with a base as a result water is formed.**

$$H^+ + OH^- \longrightarrow H_2O$$

## HEAT OF NEUTRALIZATION:

*The amount of heat evolved when one mole of Hydrogen ions ($H^+$) from an acid reacts with one mole of Hydroxide ions ($OH^-$) from an alkali to form one mole of water.*

*In other words,* the amount of heat evolved during a neutralization reaction in which one mole of water is formed is known as Heat of Neutralization.

**Examples of Heat of Neutralization**

$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$ $\quad \Delta H = -57.3 KJ/mol$

$KOH_{(aq)} + HNO_{3(aq)} \longrightarrow KNO_{3(aq)} + H_2O_{(l)}$ $\quad \Delta H = -57.3 KJ/mol$

$2NaOH_{(aq)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$ $\quad \Delta H = -(2 \times 57.3) KJ/mol$

**Note:** **The heat of neutralization for any strong acid with strong base is approximately same.**

## DETERMINATION OF HEAT OF NEUTRALIZATION

### Procedure:

Take 50 $cm^3$ of molar NaOH solution and 50 $cm^3$ of molar $HC\ell$ solution and note its temperature ($t_1$). Pour the $HC\ell$ solution in 250 $cm^3$ beaker (Calorimeter) and then add quickly NaOH solution the solution being stirred all the time, and note down the highest temperature ($t_2$) reached during the reaction. At the end, weigh the calorimeter with salt solution. Heat of neutralization is calculated by the following formula:

$$\Delta H = m \times S \times \Delta t$$

*OR* $$\Delta H = m \times S \times (t_2 - t_1)$$

### Observation and Calculations:

1. Mass of calorimeter along with stirrer $= m_1$
2. Mass of calorimeter with stirrer + salt solution $= m_2$
3. Mass of solution $(m_2 - m_1)$ $= m$
4. Specific heat of salt solution $= S$
5. Initial temperature of reactants $= t_1$
6. Final highest temperature $= t_2$
7. Increase in temperature i-e. $t_2 - t_1$ $= \Delta t$

**Heat of neutralization is given by** $\Delta H = m \times S \times \Delta t$

## EXAMPLE QUESTION:

**Q1. Calculate the heat of neutralization of NaOH by HCl when 50 ml of NaOH and 50 ml of HCl were reacted. A calorimeter of 50 g is used and its weight was found 150g taken along with solution after reaction. The temperatures were noted as 20°C and 26.8°C at the start and end of reaction respectively.**

## DATA:

**Given:**

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. | Mass of calorimeter along with stirrer | = | $m_1$ | = | 50 g |
| 2. | Mass of calorimeter with stirrer + salt solution | = | $m_2$ | = | 150 g |
| 3. | Mass of solution $(m_2 - m_1)$ | = | m | = | 100 g |
| 4. | Specific heat of salt solution | = | S | = | 4.25 J/g/°C |
| 5. | Initial temperature of reactants | = | $t_1$ | = | 20 °C |
| 6. | Final highest temperature | = | $t_2$ | = | 26.8 °C |
| 7. | Increase in temperature i-e. $(t_2 - t_1)$ | = | $\Delta t$ | = | 6.8 °C |

## REQUIRED:

Heat of neutralization = $\Delta H = ?$

**FORMULA:** Heat of neutralization = $\Delta H = m \times S \times \Delta t$

## SOLUTION:

Heat of neutralization = $\Delta H = m \times S \times \Delta t$

$$= \Delta H = 100\text{g} \times 4.25 \frac{\text{J}}{\text{g°C}} \times 6.8\text{°C}$$

$$\Delta H = 2890 \text{ J}$$

The value obtained i.e. 2890J is for 50ml of solution, as a molar solution is used therefore for 1 mole of NaOH the heat of neutralization can be calculated by the following method:

- For 50 ml of solution the heat of neutralization is 2890 J
- For 1 ml of solution the heat of neutralization is $\frac{2890 \text{ J}}{50 \text{ ml}}$
- For 1000 ml (one $dm^3$) of solution heat of neutralization is $\frac{2890 \text{ J}}{50 \text{ ml}} \times 1000 \text{ ml}$

The heat of neutralization for 1000 ml (one $dm^3$) of solution is 57800 J or 57.8 KJ. As the solution is molar so it can be written as 57.8 KJ/mol. The heat of neutralization of NaOH by HCl is **$\Delta H = -57.8$ KJ/mol.**

**Negative sign is used to represent exothermic reaction**

**The heat of neutralization of NaOH by HCl is $\Delta H = -57.8$ KJ/mol**

# EXERCISE

## 1. Fill In The Blanks:

(i) The Chemical reaction in which the heat is given out is called ***exothermic*** reaction.

(ii) [illegible] ________ [illegible]

(iii) Heat evolved or absorbed during a chemical reaction at constant pressure is called ***enthalpy of reactions.***

(iv) Acid base reaction is called ***neutralization*** reaction

(v) $C_{(s)} + O_{2\,(g)} \longrightarrow CO_{2\,(g)} \quad \Delta H = -\underline{393.7}\text{KJ / mol}$

(vi) $H_{2\,(g)} + \frac{1}{2}O_{2\,(g)} \longrightarrow H_2O_{(l)} \quad \Delta H = -\underline{286}\text{ KJ/mol}$

## 2. Tick The Correct Answers:

(i) In an exothermic reaction.
- (a) Heat energy is lost.
- (b) Heat energy is gained.
- (c) Heat energy is lost as well as gained.
- (d) None of them.

(ii) In an exothermic reaction.
- (a) Container becomes hot.
- (b) Container becomes cold.
- (c) The temperature of container remains the same.
- (d) None of them.

(iii) During an endothermic reaction.
- (a) Container used becomes cold.
- (b) Container used becomes hot.
- (c) The temperature of container used remains same.
- (d) Total energy of reactants increases.

(iv) The heat evolved during the formation of 1 mole of water from $H_2$ and $O_2$ is
- (a) 286 Kilo joules / mol
- (b) 186 Kilo joules / mol
- (c) 300 Kilo joules / mol
- (d) 200 Kilo joules / mol

(v) The formation of water form $H_2$ and $O_2$ is the example of:
- (a) Exothermic reaction.
- (b) Endothermic reaction.
- (c) Neutralization reaction
- (d) None of them.

**ANSWERS:**

| | | | | |
|---|---|---|---|---|
| i) a | ii) a | iii) a | iv) a | v) a |

**3. Write answer of the following Questions:**

(i) Define the following terms:

(a) Thermo chemistry — Answer on page 3

(b) Exothermic reaction — Answer on page 3

(c) Endothermic reaction , Answer on page 4

(ii) Give atleast two equations of exothermic and endothermic reactions.

Answer on Page 6

(iii) Which of the following are exothermic or endothermic processes?

(a) The decomposition of mercuric oxide ($HgO$). *Endothermic Reaction*

(b) The electrolysis of water. *Endothermic Reaction*

(c) The reaction of ($Na$) with water. *Exothermic Reaction*

(d) The burning of methane $CH_4$. *Exothermic Reaction*

(e) The decomposition of $KClO_3$. *Endothermic Reaction*

(f) A match burn. *Exothermic reaction*

(iv) Define the following terms:

(a) Enthalpy — Answer on page 5

(b) Enthalpy of reaction. — Answer on page 5

(v) Define heat of neutralization. What would be the value of heat of neutralization when strong acid reacts with strong base?

## HEAT OF NEUTRALIZATION

***The amount of heat evolved during a neutralization reaction in which one mole of water is formed is known as Heat of Neutralization.***

*(OR)*

***The amount of heat evolved when one, mole of Hydrogen ions ($H^+$) from an acid reacts with one mole of Hydroxide ions ($OH^-$) from an alkali to form one mole of water.***

The heat of neutralization for any strong acid with strong base is approximately same. Some examples are given below:

**e.g.**

$$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)} \quad \Delta H = -57.3 KJ/mol.$$

$$KOH_{(aq)} + HNO_{3(aq)} \longrightarrow KNO_{3(aq)} + H_2O_{(l)} \quad \Delta H = -57.3 KJ/mol.$$

$$2NaOH_{(aq)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)} \quad \Delta H = -(2 \times 57.3) KJ/mol$$

SESSION 2016-2017

PRACTICAL CENTRE KARACHI

# CLASS-IX

# CHEMISTRY

## Chapter # 11

## HYDROGEN AND WATER

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### (a) By Liquefaction:

When water gas is cooled down upto –200°C, Carbon monoxide liquefies and $H_2$ remains as gas. The traces of CO gas can be removed from the mixture by treating the mixture with caustic soda (NaOH solution) then Sodium Formate is formed.

$$CO_{(g)} + NaOH_{(aq)} \longrightarrow \underset{\text{Sodium Formate}}{HCOONa_{(aq)}}$$

### (b) By Oxidation (Bosch Process):

In this process, more steam is passed through water gas at 500°C in the presence of Iron oxide (FeO) or Chromium Oxide ($Cr_2O_3$) catalyst. Carbon monoxide gas becomes $CO_2$ gas which is soluble in water while $H_2$ remains insoluble so it can be obtained as pure gas.

$$\underbrace{CO_{(g)} + H_{2(g)}}_{\text{Water gas}} + H_2O_{(g)} \xrightarrow[500°C]{FeO} \underset{\text{Soluble in water}}{CO_{2(g)}} + 2H_{2(g)}$$

## 3. By The Thermal Decomposition of Methane:

When methane gas is heated above 700°C in absence of air then $H_2$ gas is obtained along with solid carbon black by the thermal decomposition of methane.

$$CH_{4(g)} \xrightarrow[\text{Absence of air}]{700°C} \underset{\text{Carbon black}}{C_{(s)}} + 2H_{2(g)}$$

### Use of Carbon Black (Lamp Black):

Carbon black is used in rubber industry as filler for manufacturing motor tyres. It is also used in the preparation of inks, paints, polishes, carbon papers and plastics.

## 4. By The Electrolysis of water:

$H_2$ gas can be produced by the electrolysis of water.

$$2H_2O_{(l)} \xrightarrow[\text{(acid or base)}]{\text{Electricity}} 2H_{2(g)} + O_{2(g)}$$

## Physical Properties:

1. Hydrogen is a colourless, odourless and tasteless gas.
2. It is insoluble in water.
3. It is highly inflammable gas and burns with blue flame.
4. Certain metals adsorb hydrogen on their surfaces.
5. Its electro negativity is 2.1 while its ionization energy is 13.54e.v or 1312KJ /mol.
6. Its bond dissociation energy (H – H) is 104 KCal / mol or 435KJ/mol.
7. It liquefies at - 252°C and freezes at - 259°C.

## Chemical Properties:

### 1. Decomposition of Molecular Hydrogen ($H_2$):

Molecular Hydrogen ($H_2$) contains stable covalent bond so it is relatively inert at ordinary conditions but bond breaks at very high temperature.

$$H\text{-}H \longrightarrow \underset{\text{Atomic Hydrogen}}{H + H} \qquad \Delta H = +435 KJ/mol \text{ or } +104 K cal/mol$$

# HYDROGEN AND WATER 11

## HYDROGEN

### Introduction:

[illegible]

dilute hydrochloric acid.

$$Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2\,(aq)} + H_{2\,(g)}$$

In Greek language, *Hydrogen* means ***water* producer**. This name was given by *Lavoisier.*

## OCCURRENCE:

### In Universe:

Hydrogen is one of the most abundant elements in the universe; the sun and the other stars are largely composed of Hydrogen. It is the **nuclear fuel** consumed by the sun and the other stars which produces energy. About *70* % of the universe is composed of Hydrogen.

### In Earth:

In the earth crust, Hydrogen is the $9^{th}$ most abundant element. 0.89 % of earth mass depends upon Hydrogen. It is found in negligible quantities in Free State.

### In Combined State:

In the combined state, it occurs as water ($H_2O$) which is the most abundant compound on earth. Water contains **11.11** % Hydrogen and **88.89** % Oxygen by mass. Petroleum and other organic materials also contain Hydrogen. Petroleum and natural gas are mostly hydrocarbons.

## INDUSTRIAL PREPARATION OF HYDROGEN:

### 1. By Passing Steam Over Coke (Steam – Coke Process):

At 1000°C, steam is passed over red hot coke (carbon) then a mixture of Carbon monoxide and Hydrogen gas is produced. This mixture of gases is called water gas.

$$C_{(s)} + H_2O_{(g)} \xrightarrow{1000^\circ C} \underbrace{CO_{(g)} + H_{2\,(g)}}_{\text{Water gas}}$$

### 2. From Natural Gas (Steam – Hydrocarbon Process):

At 900°C and in the presence of Nickel catalyst, steam reacts with Hydrocarbons (like methane $CH_4$) as a result water gas is produced.

$$CH_{4\,(g)} + H_2O_{(g)} \xrightarrow{Ni\,/\,900^\circ C} \underbrace{CO_{(g)} + 3H_{2\,(g)}}_{\text{Water gas}}$$

Water gas is a very good fuel and is also used in the preparation of methanol (Methyl alcohol).

$H_2$ gas can be separated from water gas by the following methods:

(a) By liquefaction (b) By oxidation (Bosch Process).

## 2. As a Reducing Agent:

Hydrogen shows greater affinity for Oxygen and reduced many metal oxides into free metals:

$$CuO_{(s)} + H_{2(g)} \xrightarrow{\text{Heat}} \underset{\text{Copper}}{Cu_{(s)}} + H_2O_{(g)}$$

$$WO_{3(s)} + 3H_{2(g)} \xrightarrow{\text{Heat}} W_{(s)} + 3H_2O_{(g)}$$

## 3. Hydrogenation Reaction (Addition of Hydrogen):

The addition of Hydrogen into other molecular compounds is called Hydrogenation reaction. When molecular (covalent) compounds react with hydrogen and heated in presence of Pt, Pd or Ni catalysts then addition products are obtained.

(i) $$\underbrace{CO_{(g)} + 2H_{2(g)}}_{\text{water gas}} \xrightarrow[400^\circ C/\text{high pressure}]{ZnO/Cr_2O_3} \underset{\text{Methyl alcohol}}{CH_3-OH_{(l)}}$$

(ii) $$\underset{\substack{\text{Unsaturated Hydrocarbon} \\ \text{(Liquid)}}}{\text{Edible oils}} \xrightarrow[H_{2(g)}]{\text{Ni / high Temp}} \underset{\substack{\text{Saturated Hydrocarbon} \\ \text{(Solid)}}}{\text{Vegetable Ghee}}$$

## 4. Reaction with Metals:

Alkali metals (Na, K, etc) and alkaline earth metals (Ca, Ba, etc) react with Hydrogen on heating to form ionic Hydrides.

$$2Na_{(s)} + H_{2(g)} \xrightarrow{200^\circ C} \underset{\text{Sodium hydride}}{2\,NaH_{(s)}}$$

## 5. Reaction With Non – Metals:

Hydrogen reacts with many non-metals under different conditions to form addition products.

$$2H_{2(g)} + O_{2(g)} \xrightarrow{\text{Ignition}} 2H_2O_{(l)}$$

$$N_{2(g)} + 3H_{2(g)} \underset{Fe_2O_3.Al_2O_3}{\overset{450^\circ C/200\text{-}250atm}{\rightleftharpoons}} 2NH_{3(g)}$$

## Uses:

1. It is used in weather balloons.
2. It is used as a fuel in the form of water gas.
3. Hydrogen is used in the manufacture of fertilizers.
4. It is used in the manufacture of tungsten bulb filaments.
5. It is used (as reducing agent) for the purification of metals.
6. It is used in the manufacture of vegetable ghee by edible oils.
7. It is used in the preparation of chemicals like $NH_3$, $CH_3OH$, etc.
8. Hydrogen is used in the formation of **Hydrogen torch** which is used cutting and welding (temperature reaches up to 4000°C).

## Nascent Hydrogen:

Hydrogen at the time of its generation during a chemical reaction is called Nascent (newly born) Hydrogen. It is found in atomic form so it is chemically more reactive than Molecular Hydrogen.

$$2HCl_{(aq)} + Zn_{(s)} \longrightarrow ZnCl_{2(s)} + 2[H]$$

## Example:

Consider the brownish colour acidic Ferric Chloride ($FeCl_3$), when $H_2$ gas is passed through it, no change is observed but when a piece of Zn metal is added in the solution, then Nascent Hydrogen is generated which reduces $FeCl_3$ to $FeCl_2$ (greenish in colour).

$$FeCl_{3(aq)} + H_{2(g)} \longrightarrow \text{No reaction}$$

$$FeCl_{3(aq)} + \underset{\text{Nascent hydrogen}}{[H]} \xrightarrow{Zn/HCl} FeCl_{2(aq)} + HCl_{(aq)}$$

## ISOTOPES OF HYDROGEN:

*"The atoms of an element having same atomic number but different atomic masses are called isotopes."*

*OR*

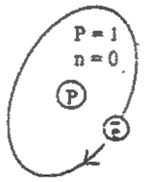
*"The atoms of an element contain same number of protons but different number of neutrons in the nuclei is called Isotopes."*

Following are the three isotopes of hydrogen:

(i) **Protium** (ii) **Deuterium** (iii) **Tritium**

### (i) Protium or Ordinary Hydrogen Atom($^1_1H$):

Protium (Hydrogen) contains one proton without any neutron in the nucleus while one electron is present in its first orbit (shell). Its atomic number is 1 and mass number is also 1. It is found about 99.98%. It is stable isotope of Hydrogen.

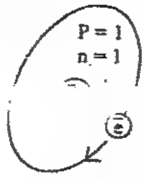



**Protium ($^1_1H$)**

### (ii) Deuterium (D or $^2_1H$):

Deuterium contains one proton and one neutron in the nucleus while one electron is present in its first orbit (shell). Its atomic number is 1 and its mass number is 2. It is found about 0.0156 % (1:15000). It is also a stable isotope of Hydrogen.

It is known as heavy Hydrogen. Deuterium was discovered in 1931 by Urey.

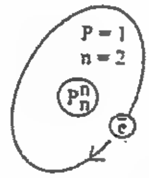



**Deuterium ($^2_1D$ or $^2_1H$)**

### (iii) Tritium (T or $^3_1H$):

Tritium contains one proton and two neutrons in the nucleus while one electron is present in its first orbit (shell). Its atomic number is 1 and mass number is 3. It occurs in negligible quantities about $4 \times 10^{-15}$ %.

It is radioactive isotope of Hydrogen with half life about 12.5 years. It is used as moderator in the nuclear reactions while as a tracer in biochemical tests.




**Tritium ($^3_1T$ or $^3_1H$)**

## WATER:

### Introduction:

Water is one of the most abundant compounds on earth. Water is a universal solvent. Water which is found in the nature is known as *natural water*. On the other hand water which has obtained by some treatments is known as *treated water*. Distilled water is the purest form of water.

### Physical Properties:

(1) Water is a colourless, tasteless and odourless liquid.

(2) At 4°C its density is about 1.00g/cm$^3$.

(3) Its melting point is O°C while boiling point is 100°C.

(4) Water possesses many unusual properties due to hydrogen bonding, for example it melts and boils at much higher temperature than other liquids.

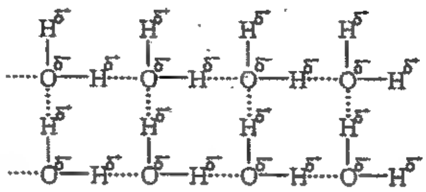
(5) It is one of the few substances that expand upon freezing.

### Anomalous Behaviour of Water:

When boiled water is allowed to cool down from 100°C to 4°C, molecules contract but it expands on further cooling from 4°C to O°C which is against the law. This irregular behaviour of water is called ***Anomalous Expansion of Water***.

## Reasons for Anomalous Behaviour of Water:

Water is a polar molecule so water molecules are associated by means of Hydrogen bonding, in which the slightly positive Hydrogen atom is attracted by the slightly negative Oxygen atom of other water molecule. This type of inter molecular forces of attraction between the polar molecules is called **dipole-dipole interaction** while polar molecule contains Hydrogen then this attraction is also called **Hydrogen bonding**. It is denoted by dotted lines. Hydrogen bond is ***secondary bond.***



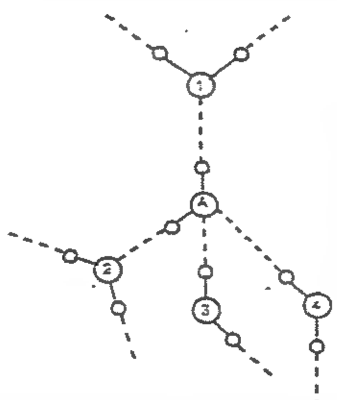
**Hydrogen Bonding**

Although Hydrogen bonding is the strongest **secondary bonds** but it is still weaker than normal7 covalent bonds. The Hydrogen bond affects the physical properties of a substance such as melting point, boiling point, heat of fusion, etc.

**When water is heated from 0°C to 4°C it shows contraction instead of expansion. Similarly when it cools down from 4°C to 0°C it shows expansion rather than contraction.**

## Application (Use) of Anomalous Expansion of Water:

Due to anomalous behaviour of water, the aquatic animals survive in the winter season in cold regions where temperature reaches much below 0°C. When temperature falls during winter season, water of the sea is cooled and **contracts** till 4°C, On further lowering temperature, water on the surface becomes ice which floats above the surface of water at 4°C because **ice** is **lighter** than **water** at 4°C. The aquatic animals go down in the water at 4°C, dissolved oxygen is sufficient of their survivals through out the winter season.




**STRUCTURE OF ICE**

# CHEMICAL PROPERTIES OF WATER

## 1- Reaction With Metals:

Water reacts with metals in number of ways. The degree of reactivity depends upon the nature of the metals and their positions in the electrochemical series.

### (a) More Electropositive Metals (Alkali and Alkaline Earth Metals):

Sodium, Potassium, (from IA) Calcium (from IIA) react with cold water to form their hydroxides with the liberation of $H_2$ gas. Sodium and potassium reacts vigorously while Calcium reacts slowly.

$$2Na_{(s)} + 2H_2O_{(l)} \xrightarrow{\text{cold}} 2NaOH_{(aq)} + H_{2(g)} \quad \text{(Fast)}$$

$$2K_{(s)} + 2H_2O_{(l)} \xrightarrow{\text{cold}} 2KOH_{(aq)} + H_{2(g)} \quad \text{(Fast)}$$

$$Ca_{(s)} + 2H_2O_{(l)} \xrightarrow{\text{cold}} Ca(OH)_{2(aq)} + H_{2(g)} \quad \text{(Slow)}$$

| | |
|---|---|
| K, Na, Ca | More |
| Mg, Al, Zn, Fe, Pb | Less |
| H | |
| Cu, Ag, Hg, Au | Noble |

### (b) Less Electropositive Metals:

Less electropositive metals like magnesium, zinc, iron, etc. react with hot water to form their oxides with the liberation of $H_2$ gas.

$$Mg_{(s)} + H_2O_{(l)} \xrightarrow{\text{hot}} MgO_{(s)} + H_{2(g)}$$

$$Zn_{(s)} + H_2O_{(l)} \xrightarrow{\text{hot}} ZnO_{(s)} + H_{2(g)}$$

$$3Fe_{(s)} + 4H_2O_{(g)} \underset{\text{hot}}{\overset{\text{red}}{\rightleftharpoons}} Fe_3O_{4(s)} + 4H_{2(g)}$$

**NOTE: Heavy (Noble) metals like, Copper, Silver, Mercury and Gold do not react with water.**

## 2- Reaction With Non-Metals:

### (a) With Chlorine (Bleaching Action):

Chlorine reacts with water to produce hydrochloric acid (**HCl**) and Hypochlorous acid (**HOCl**). Hypochlorous acid is unstable and readily liberates atomic oxygen which can bleach dyes and kill bacteria by oxidation. Therefore, Chlorine in water acts as bleaching and oxidizing agent.

$$Cl_{2(g)} + H_2O_{(l)} \rightleftharpoons HCl_{(aq)} + HOCl_{(aq)}$$

$$\underset{\text{acts as oxidizing and bleaching agent}}{HOCl_{(aq)}} \longrightarrow HCl_{(aq)} + [O]$$

$$[O] + [O] \longrightarrow O_{2(g)}$$

### (b) With Carbon:

At 1000°C, steam is passed over red hot coke (carbon) then a mixture of Carbon monoxide and Hydrogen gas is produced. This mixture of gases is called **water gas**.

$$C_{(s)} + H_2O_{(g)} \xrightarrow{1000^\circ C} \underbrace{CO_{(g)} + H_{2(g)}}_{\text{water gas}}$$

### (c) With Silicon:

Silicon reacts with steam at very high temperature to form silicon dioxide with the liberation of $H_2$ gas.

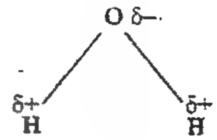
$$Si_{(s)} + 2H_2O_{(g)} \xrightarrow{\text{high temp.}} SiO_{2(s)} + 2H_{2(g)}$$

### 3. Reaction with Calcium Oxide (Quick lime):

Calcium oxide partially dissolves in water to form Calcium Hydroxide (i.e lime water).

$$\underset{\text{quick lime}}{CaO_{(s)}} + H_2O_{(l)} \longrightarrow \underset{\text{lime water}}{Ca(OH)_{2\,(aq)}}$$

## WATER AS UNIVERSAL SOLVENT:



...ter is an excellent solvent. It dissolves ionic and polar covalent compounds. It can dissolve more substances than any other solvent. The great dissolving power of water is due to its polar nature. One side of water molecule is slightly positive while the other side is slightly negative (this effect is also called dielectric).

As a result of polar nature, water is an excellent solvent for:

Electrovalent (ionic) solutes like salts, mineral acids and bases.

e.g. NaCl, $HNO_3$, HCl, $H_2SO_4$, NaOH, etc.

Covalent compounds which contain hydroxyl group (–OH) also dissolve in water.

e.g. glucose, sugar, alcohols, etc.

Gases also dissolve in water like ammonia, hydrogen chloride, nitrogen pentaoxide ($N_2O_5$) etc. Other gases like $SO_2$, $CO_2$, $Cl_2$ are fairly soluble in water. The solubility of gas decreases with the increase in temperature.

## WATER OF CRYSTALLIZATION:

During the process of crystallization, some water molecules are surrounded by the ions of salt (solute). These water molecules are known as ***Water of crystallization***.

The salts containing water molecules are generally known as ***Hydrates***.

**Examples:**

$CuSO_4 . 5H_2O$, $FeSO_4 . 7H_2O$, $Na_2CO_3 . 10H_2O$, $AlCl_3 . 6H_2O$, $BaCl_2 . 2H_2O$, etc.

$$CuSO_{4\,(s)} + 5H_2O_{(l)} \xrightarrow{\text{crystallization}} CuSO_4 . 5H_2O_{(s)}$$

## HEAT OF HYDRATION:

The minimum amount of heat liberated in the formation of Hydrate is called **heat of hydration**. The water of crystallization molecules are easily dissociated from their salt crystals by heating. The residue left behind is then said to be **Anhydrous** (shapeless) or **Anhydrate**.

$$\underset{\text{Hydrated (blue crystals)}}{CuSO_4 . 5H_2O_{(s)}} \xrightarrow{\text{heat}} \underset{\text{Anhydrous (white powder)}}{CuSO_{4(s)}} + 5H_2O_{(g)}$$

## HYGROSCOPIC SUBSTANCES:

The substances which absorb moisture from atmosphere are called *Hygroscopic substances*.

e.g. Most of the salts of nitrate ($NO_3^-$) are hygroscopic. $NaNO_3$ , $Al(NO_3)_3$

Calcium chloride ($CaCl_2$), Quick lime (CaO), Copper oxide (CuO) and Sulphuric acid ($H_2SO_4$), Silica gel, etc.

Hygroscopic substances are commonly used as drying agents in the laboratory.

## TYPES OF WATER:

There are two types of water in this universe:

(i) Natural (ordinary/light) Water (ii) Heavy Water

## TYPES OF NATURAL (Ordinary or Light) WATER:

There are two types of natural water in this universe:

(i) Soft Water (ii) Hard Water

### (i) SOFT WATER:

"Water which easily produces more lather with soap is called Soft Water."

Soft water contains salts of **Sodium (Na) and Potassium (K)** which do not resist to the formation of lather.

### (ii) HARD WATER:

"Water which does not produce lather with soap but produce curd is called Hard Water."

Hard water contains **salts of Magnesium (Mg) and Calcium (Ca)** which resist to the formation of lather but they produce curd like precipitate (ppt).

### Types of Hard Water:

There are two types of hard water:

(i) Temporary Hard Water (ii) Permanent Hard Water

### (i) Temporary Hard Water:

"If the hardness can be removed then water is called Temporary hard water."

Temporary hardness of water is due to the presence of bicarbonates ($HCO_3^-$) of Magnesium (Mg) and Calcium (Ca) in water. These salts are soluble in water and are present in the form of ions.

$$Mg(HCO_3)_{2\,(aq)} \longrightarrow Mg^{++}_{(aq)} + 2\,HCO^-_{3\,(aq)}$$

$$Ca(HCO_3)_{2\,(aq)} \longrightarrow Ca^{++}_{(aq)} + 2\,HCO^-_{3\,(aq)}$$

### (ii) Permanent Hard Water:

"If the hardness of water can not be removed then water is called Permanent hard water."

Permanent hardness of water is due to the presence of Chlorides ($Cl^-$) or Sulphates ($SO_4^{2-}$) of Magnesium (Mg) and Calcium (Ca) in water. These salts are also soluble in water and are present in the form of ions.

$$MgSO_{4\,(aq)} \longrightarrow Mg^{++}_{(aq)} + SO^{2-}_{4\,(aq)}$$

$$CaCl_{2\,(aq)} \longrightarrow Ca^{++}_{(aq)} + 2\,Cl^-_{(aq)}$$

## Causes of Hardness of Water:

Hard water contains salts of Magnesium (Mg) and Calcuim (Ca) with bicabonates ($HCO_3^-$), Sulphates ($SO_4^{2-}$) and Chorides ($Cl^-$).

The rain water on its way to flow on the ground, dissolved Carbon dioxide gas from the atmosphere. This water while flowing through soil or rocks containing Carbonates of Mg and Ca react with dissolved $CO_2$ in water to change the carbonates into bicarbonates.

$$MgCO_{3(s)} + CO_2 + H_2O_{(l)} \longrightarrow Mg(HCO_3)_{2(aq)}$$

$$CaCO_{3(s)} + CO_2 + H_2O_{(l)} \longrightarrow Ca(HCO_3)_{2(aq)}$$

Underground water also dissolved Chlorides and Sulphate of Mg and Ca. This underground water now contains $Mg^{2+}$ and $Ca^{2+}$ ions which causes hardness in water.

## METHODS TO REMOVE HARDNESS:

**For Temporary Hard Water:** (i) By Heating (ii) Clark's Method

**For Permanent Hard Water:** (iii) Ion Exchange Method

### (i) By Heating:

**Temporary hardness** can easily be removed by boiling. This hardness is due to the presence of dissolved Magnesium bicarbonate and Calcium bicarbonate, which decompose on heating to $MgCO_3$ and $CaCO_3$ which are insoluble and are removed by filteration.

$$Ca(HCO_3)_{2(s)} \xrightarrow{\text{Boil}} \underset{\text{Insoluble}}{CaCO_{3(s)}} + CO_{2(g)} + H_2O_{(l)}$$

### (ii) By Clark's Method (Addition of Lime Water):

**Temporary hardness** can also be removed by using Lime water $Ca(OH)_2$. In this method temporary hard water containing bicarbonates of *Mg* and *Ca* is treated with Lime water in the tanks. The bicarbonates of *Mg* and *Ca* are converted into their insoluble carbonates. The insoluble carbonates settled down at the bottom of tanks while soft water is drained off for the use.

$$Ca(HCO_3)_{2(aq)} + Ca(OH)_{2(aq)} \longrightarrow \underset{\text{Insoluble}}{2CaCO_{3(s)}} + 2H_2O_{(l)}$$

$$Mg(HCO_3)_{2(aq)} + Ca(OH)_{2(aq)} \longrightarrow MgCO_{3(s)} + CaCO_{3(s)} + 2H_2O_{(l)}$$

### (iii) By Ion Exchange Method (Zeolite or Permutit Method):

**Permanent hardness** can be removed by using Ion Exchange method. In this method Magnesium and Calcium ions from water are removed as insoluble precipitates through the Sodium Zeolite. They form insoluble precipitates of *Mg* and *Ca*.

Sodium Zeolite is a naturally occurring Sodium Aluminium Silicate. The Sodium ions will go into the solution while the unwanted *Mg* and *Ca* ions precipitate with zeolite.

$$CaSO_{4(aq)} + Na_2-Zeolite_{(aq)} \longrightarrow \underset{\text{insoluble}}{Ca-Zeolite_{(s)}} + Na_2SO_{4(aq)}$$

Sodium zeolite can be regenerated by passing a concentrated NaCl solution through Ca – Zeolite.

$$Ca - Zeolite_{(s)} + 2NaCl_{(aq)} \longrightarrow Na_2 - Zeolite_{(aq)} + CaCl_{2(aq)}$$

## DISADVANTAGES OF HARD WATER:

### 1. Wastage Of Soap:

Hard water consumes a larger amount of soap in washing process. Some of soap is [illegible] where the Magnesium and Calcium ions in the form of soap-curds. Therefore, hard water requires more amount of soap than soft water.

### 2. Harmful For Health:

If hard water is used for drinking purpose for long time it may cause dysentry or other stomach disorders. If hardness is due to Magnesium Sulphate then drinking of such water weakens the stomach function.

### 3. Unfit For Steam Engines:

Hard water is unfit for use in steam engines and turbine. When hard water is heated in the boiler for producing steam, Magnesium and Calcium salts settle down as a hard insulating core on the bottom which requires large amount of heat to produce steam. Hence more fuel is consumed. If these deposit are not removed then they block the tubes due to this extra pressure causes explode the boiler.

## DRINKING WATER:

Water is essential for the survival of any form of life. On an average, a human being consumes about ***two liters*** of water every day. Water account for about 70 percent of the weight of a human body. Water is used for drinking, domestic, agriculture, industrial purposes.

In our home, water is used for drinking, cooking and washing purposes. Although there is an enormous quantity of water in the world. The reservoirs of fresh and quality water are very limited. Human activities are destroying the quality of water. The quality as well as quantity of clean water supplied is vital for the welfare of mankind.

## QUALITY OF DRINKING WATER (Potable Water):

Municipal water is mainly used for drinking, cleaning, and other domestic purposes. The water that is fit for drinking purpose is called **potable water**, it should be free from all sorts of pollutants.

Some characteristics of potable water are given as:

1. It should be colourless, odoureless and tasteless.
2. It should have a pH in the range of 7.0 - 8.5.
3. It should be free from germs. bacteria and other pathogenic oraganisms.
4. It should not contain any toxic dissolved impurity such as heavy metals and pesticides.
5. It should be moderately soft. Its hardness should not be above 150 p.p.m (parts per million).

## TREATMENT FOR DRINKING WATER:

The water supplied for drinking and other domestic uses, has to be treated before the supply for the domestic purpose. The raw or impure water obtained from sources such as rivers, lakes, wells and tube wells, etc. should undergo treatment by various steps to make it fit such as:

1. Aeration 2. Settling 3. Coagulation 4. Filtration

5. Chlorination (sterilization to destory bacteria and pathogenic organism)

## WATER POLLUTION:

The mixing of unwanted materials in drinking (**potable**) water is called water pollution. Natural water is polluted by sewage, indusrial wastes and wide range of synthetic chemicals.

### Classification of Water Pollutants:

There are variuos types of water pollutants which can broadly be classified into different catagories:

### 1. Oxygen – Demanding Wastes (ODW):

These include domestic and animal sewage, bio–degradable organic compounds and industrial wastes from food – processing plants, meat packing plants, slaughter houses, paper and pulp mills, tanneries, etc. All these wastes undergo degradation and decompsition due to which there is a rapid **depletion of oxygen** (D.O) from water which is harmful to aquatic animals. Many aquatic animal can not survive at lower D.O level in water.

### 2. Synthetic Organic Compounds (SOC):

These are man-made materials such as synthetic pesticides, synthetic detergents, food additives, pharmaceuticals, insecticides, paints, fibres, solvents, plastics, etc. These materials are potentially toxic to plants, animals and human. They cause the adverse effects of water like change in colour, odour and taste.

### 3. Disease Causing Wastes (Micro Organisms):

Disease causing wastes include pathogenic micro-oraganisms which may enter water along with sewage and other wastes and may cause damage the public health. These microbes. (viruses and bacteria) can cause dangerours ***Water Borne Diseases*** (WBD) such as Typhoid, Cholera, Polio, Dysentary, Hepatitis in humans.

### 4. Agricultural Water Pollution (AWP):

In modern agricultural, pesticides, fertilizers and organic wastes (manure) are essential for producing high yields of crops required for the world's growing population. There are over one thousand chemical compounds that are currently being used.

## ORDINARY WATER:

"Water molecules which contain Protium (isotope of Hydrogen) are called Ordinary or light water."

## HEAVY WATER:

"Water molecules which contain Deuterium (heavy isotope of Hydrogen) are called Heavy water."

Heavy water is present in natural water to the extent of 1:7000. It is composed of oxygen with heavier isotope of Hydrogen i.e Deuterium of mass 2 amu. The physical **properties are different** from ordinary water but **chemical properties are similar.**

### Comparison Of Heavy Water With Ordinary Water

| Property | Ordinary Water | Heavy Water |
|---|---|---|
| Formula | $H_2O$ | $D_2O$ |
| Molecular mass | 2+16 = 18amu. | 4+16 = 20amu. |
| Density g/cm$^3$ at O°C | 1.00 g/cm$^3$ | 1.11 g/cm$^3$ |
| Maximum Density at | 4°C | 11.6°C |
| Freezing point | 0.0° | 3.8°C |
| Boiling point | 100°C | 101°C |

## USES (APPLICATIONS):

1. It is used as "Moderator" in nuclear fission power reactors for slowing down the speed (velocity) of neutrons.
2. Heavy water is used as tracer in biochemical researches.
3. It is also used as a source of heavy Hydrogen for Hydrogen bombs.



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## EXERCISE:

### 1.(a) Fill in the blanks:

(i) Natural Hydrogen contains 0.0156 % (percent) deuterium.

(ii) Nascent Hydrogen is more reactive than molecular Hydrogen

(iii) Tritium is an isotope of Hydrogen, its mass number is 3 .

(iv) Natural Hydrogen is a mixture of three isotopes namely **Protium, Deuterium** and **Tritium.**

(v) The bond energy of $H_2$ is **435 KJ /mol.**

(vi) The latent heat of fusion of ice is approximaterly **$3.36 \times 10^5$ Joules** per **Kilogram (kg).**

(vii) Ice **floats** over water because ice is **lighter** than water.

(viii) The sterilization or disinfection of water is done by **Chlorination** to destroy **Microrganisms.**

(ix) Water molecules are associated together by means of **water of crystallization.**

(x) Water is called **universal** solvent.

### (b) Point out True and False in the following statements:

(i) Ordinary hydrogen is called protium. **(True)**

(ii) Hydrogen is a good oxidizing agent. **(False)**

(iii) Deuterium contains one proton and two neutrons in the nucleus. **(False)**

(iv) Hydrogenation is the process of addition of hydrogen. **(True)**

(v) Electrolysis of water in the presence of acid liberates $H_2$ gas at the cathode and $O_2$ gas at anode. **(True)**

### (c) Multiple choice questions:

(i) Select all those things which result when Sodium metal is placed in a beaker of water:

**(a) $H_2$ and NaOH** (b) Sodium disappears after sometime
(c) Water becomes acidic (d) No action

(ii) Hydrogen is a diatomic molecule with bond energy:

(a) 200 KJ/mol (b) 100 KJ/mol
**(c) 104 K. Cal / mol** (d) 150 K. Cal / mol

(iii) Deuterium is present in natural hydrogen in the ratio:

(a) 1:1200 **(b) 1:15000** (c) 100: 50000 (d) 1: 18000

(iv) The electronegativity of Hydrogen is:

(a) 2.1 (b) 3.0 (c) 2.5 (d) 1.0

(v) A human being consumes water about ________ every day.

(a) 5litres (b) 2 litres (c) 1 litres (d) 10 litres

(vi) Polluted water is ________ for drinking purposes.

(a) unfit (b) fit ...

(vii) Molar mass of heavy water is:

(a) 18g (b) 22g (c) **20g** (d) 16g

(viii) The maximum density of water at 4°C is:

(a) **1.0 g/cm$^3$** (b) 0.998g/cm$^3$ (c) 0.918g/cm$^3$ (d) 1.2g/dm$^3$

(ix) The freezing point of heavy water is:

(a) 0°C (b) **3.8°C** (c) 4°C (d) 1°C

2.(a) Describe some of the main physical properties of water. What do you understand by the anomalous behaviour of water? What is the significance of this unusual behaviour of water?

**Answer on Page# 7 and 8**

(b) Complete the following reactions.

(i) $2Na + 2H_2O \longrightarrow 2NaOH + H_2$

(ii) $3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2$

(iii) $C + H_2O \longrightarrow \underbrace{CO + H_2}_{\text{Water gas}}$

(iv) $Cl_2 + H_2O \longrightarrow HCl + HOCl$

(v) $CaO + 2H_2O \longrightarrow Ca(OH)_2 + H_2$



3. (a) Define isotope. Disucss various isotopes of Hydrogen.

**Answer on Page # 6 and 7**

(b) How is Hydrogen prepared commercially from coke?

**Answer on Page # 3**

(c) Give Bosch method to separate Hydrogen gas from water gas.

**Answer on Page # 4**

4. (a) Give reaction of $H_2$ with:

(i) Ethene (ii) Ca (iii) S (iv) $Cl_2$

(i) $\underset{\text{Ethene}}{C_2H_4} + H_2 \longrightarrow \underset{\text{Ethane}}{C_2H_6}$

(ii) $Ca + H_2 \longrightarrow CaH_2$

(iii) $S + H_2 \longrightarrow H_2S$

(iv) $Cl_2 + H_2 \longrightarrow 2HCl$

(b) Describe the uses of Hydrogen.

**Answer on Page # 5**

(c) Show hydrogen is a good reducing agent.

**Answer on Page # 5**

5. (a) What is nascent Hydrogen? Describe its reactivity.

**Answer on Page # 6**

(b) What happens when?

(i) Mg metal is reacted with hot water.

**Answer** $Mg + 2H_2O \xrightarrow{hot} Mg(OH)_2 + H_2$

(ii) Methane is heated above 700°C in the absence of air.

**Answer on Page # 4**

(iii) Water gas is heated under pressure in the presence of $ZnO - Cr_2O_3$.

**Answer on Page # 5**

(iv) A piece of Zn metal is added to the acidic solution of $FeCl_3$.

**Answer on Page # 6**

6. (a) What do you mean by hard water? Describe the types of hardness. How is the hardness of water removed? Describe the disadvantages of hard water.

**Answer on Page # 11 and 12**

(b) What is water of crystallization? Write the formula of some of the Hydrates. What happens when Hydrates are heated? Define heat of Hydration.

**Answer on Page # 10**

(c) What is "potable water"? Write four main characteristics of potable water.

**Answer on Page # 13**

(d) Name only some common treatments to make municipal water fit for drinking purposes.

**Answer on Page # 14**

7. (a) Write notes on:

(i) Heavy water and — **Answer on Page # 15**

(ii) Hygroscopic substances. — **Answer on Page # 10**

(b) Describe some chemical characteristics of water.

**Answer on Page # 8 and 9**

(c) Name water– borne diseases that are caused by micro – organisms present in water. Name various types of water pollutants and their different catagories.

**Answer on Page # 14**

8. Point out True or False in the following statements.

(i) Water is non – polar. **(False)**

(ii) Temporary hardness in water is due to dissolved hydrogen carbonates of Ca and Mg. **(True)**

(iii) Permutit is Sodium Aluminium Silicate, commonly called Sod. zeolite. **(True)**

(iv) The molecular formula of heavy water is $H_2O$. **(False)**

(v) Conc. $H_2SO_4$ absorbs moisture from atmosphere four time of its original volume. **(False)**

SESSION
2016-2017

PRACTICAL CENTRE KARACHI

# CLASS-IX

# CHEMISTRY

## Chapter # 12

## CARBON SILICON AND THEIR COMPOUNDS

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# CARBON, SILICON AND THEIR COMPOUNDS 12





## INTRODUCTION:

Carbon and silicon belong to IV-A group in the periodic table. **Carbon** is a **non-metal**. **Silicon** is a **metalloid** and plays an important ... technologies.

| Name | $1^{st}$ shell | $2^{nd}$ shell | $3^{rd}$ shell | $4^{th}$ shell |
|---|---|---|---|---|
| Carbon ( $_6C$ ) | $K^2$ | $L^4$ | - | - |
| Silicon ( $_{14}Si$ ) | $K^2$ | $L^8$ | $M^4$ | - |

## OCCURRENCE OF CARBON:

Carbon is the **sixteenth** ($16^{th}$) most abundant element in the earth crust. Carbon occurs in the free state as well as in the combined state in the earth's crust.

### Free State:

In free state carbon occurs in the following forms: .

**(1) Amorphous Forms:**

(a) Coal (b) Lamp black (c) Wood charcoal

(d) Animal charcoal (e) Coke

**(2) Crystalline Forms:**

(a) Diamond (b) Graphite (c) Bucky balls

## (1) AMORPHOUS FORMS OF CARBON:

a) COAL

However the major source of carbon is **coal**. Coal is a complicated mixture of chemical substances containing Carbon. Compounds of Carbon exist with Hydrogen, Oxygen, Nitrogen, Sulphur and many other elements. The amount of carbon depends upon the stage of conversion of the plant materials into coal.

**$1^{st}$ Stage: (Peat)** The first stage, brown spongy material **Peat** is formed by partial decomposition of plant materials.

**2nd Stage: (Lignite)** The second stage, soft brown coal **Lignite** and then **Bitumen** is formed by the conversion of **Peat**.

**3rd Stage: (Anthracite)** The third stage, hard black coal **Anthracite** is formed by the conversion of **Bitumen.**

Note: Anthracite is the hardest form of coal

b) **LAMP BLACK (CARBON BLACK):**

Lamp black is produced by heating methane gas at 700°C in absence of air.

$$CH_{4(g)} \xrightarrow{700^\circ C} \underset{\text{Carbon black}}{C_{(s)}} + 2H_{2(g)}$$

c) **WOOD CHARCOAL** is formed when **wood** is heated strongly in the absence of air. It is used to remove offensive odour from air and colours from water.

d) **ANIMAL CHARCOAL** is formed when **bones of animal** are heated strongly in the absence of air. It is used in the gas mask to survive in the poisonous air.

e) **COKE** is formed when **coal** is heated strongly in the absence of air. It is widely used as reducing agent in metallurgical operations.

**The % of Carbon and Energy Values**

| S.No. | Fuels | Carbon Content (% mass) | Energy Value (KJ/Kg) |
|---|---|---|---|
| 1. | Wood | 50.0% | 19800 |
| 2. | Peat | 59.9% | 18700 |
| 3. | Lignite | 51.8% | 20900-25700 |
| 4. | Bitumen | 78.7% | 32100 |
| 5. | Anthracite | 91.0% | 32600 |

## COMBINED STATES:

In combined state (in the form of compounds) Carbon occurs as natural gas and petroleum. Both natural gas and petroleum are mixtures of hydrocarbons i.e. compounds of Carbon and Hydrogen elements. Carbon also occurs in the form of Carbon monoxide and Carbon dioxide in the atmosphere and also as metal carbonates in the earth's rocks. The most common carbonate rock is Calcium carbonate ($CaCO_3$) which occurs as marble, chalk and lime stone.

## ALLOTROPY:

The existence of an element in two or more different forms is called **Allotropy** and different forms are called **Allotropes** or **Allotropic forms.**

Chemical properties of allotropic forms are same but they have different physical properties due to different structures ...

## (2) CRYSTALLINE FORMS OF CARBON:

### Allotropic forms of Carbon:

There are three crystalline allotropic forms of carbon:

(a) Diamond (b) Graphite (c) Bucky Balls

## OCCURRENCE:

| DIAMOND | GRAPHITE |
|---|---|
| Diamond is found chiefly in South Africa, Brazil, Australia and India. The black coloured diamonds are called **Bort** or **Carbando** which are low in cost. | Graphite occurs naturally as **plumbago** an opaque black solid. It is found in Siberia, Canada and Sri Lanka. |

## DIFFERENCES:

| (a) DIAMOND | (b) GRAPHITE |
|---|---|
| Diamond is transparent and bright in pure state. | Graphite is a dark grey colour and dull metallic luster. |
| It is the hardest substance. | It is a soft substance and greasy to feel. |
| Its density is $3.51 g/cm^3$. | Its density is $2.2 g/cm^3$. |
| Its melting point is 3500°C. | Its melting point is 3000°C. |
| It is bad conductor of electricity. | It is good conductor of electricity. |
| Diamond is burnt in presence of oxygen to produce $CO_2$ gas. $C_{(s)} + O_{2(g)} \xrightarrow{2400°C} CO_{2(g)}$ | Graphite is burnt in presence of oxygen to produce $CO_2$ gas. $C_{(s)} + O_{2(g)} \xrightarrow{2200°C} CO_{2(g)}$ |

## USES OF DIAMOND:

(1) Coloured diamonds are used as **gems** and precious stones in Jewellery.

(2) **Bort** or **carbando** (black diamond) is used for cutting glasses and for drillings and borings of rocks.

## USES OF GRAPHITE:

(1) Graphite is used as black pigment in paints.

(2) It is used in the preparation of electrodes.

(3) It is used as neutrons – moderator in nuclear reactions.

(4) It is mixed with oil to form a high temperature lubricant.

(5) It leaves black mark on paper so it is used in the manufacture of lead pencils (graphite + clay).

## STRUCTURE:

| DIAMOND | GRAPHITE |
|---|---|
| (1) Each Carbon atom is covalently bonded with **four** other Carbon atoms to give a basic **tetrahedral unit**. These basic tetrahedral units unite with one another indefinitely forming a giant three – dimensional structure due to this, diamond is the hardest known substance. | (1) Each carbon atom is covalently bonded with **three** other Carbon atoms to give a basic **hexagonal unit**. These basic units are held together by weak Vander Waal's forces of attraction over layer by layer these layers slide over one another due to this, graphite is very soft and slippery. |
| (2) Diamond is the bad conductor of electricity because there is no free electron in the crystal of diamond. | (2) Graphite is the good conductor of electricity because only three of the four valence electrons are held in definite bond formation so the fourth electron is delocalized over the whole layer. |
| (3) The C – C bond length in diamond is **1.54A°** and bond energy for each **C – C** bond is **347KJ/mol.** | (3) (The **C – C** bond length in graphite is **3.35A°** and bond energy for each **C – C** bond is **232KJ/mol.** |

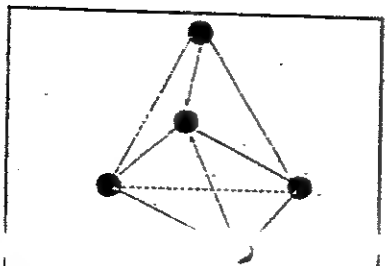


Fig 'A'
Basic tetrahedral unit of diamond
• = Carbon atom
– = Carbon to carbon Covalent bond

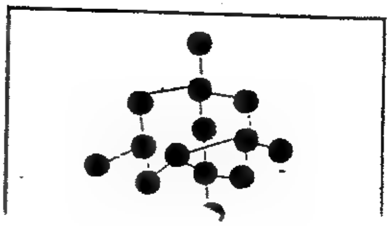
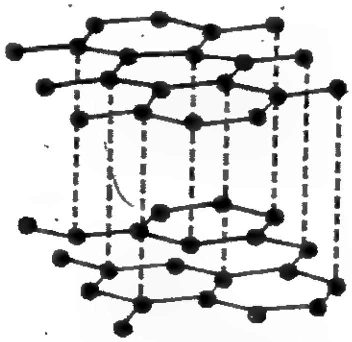


Fig 'B'
Three dimensional arrangements of carbon atoms in diamond.



Structure of Graphite



## (c) BUCKY BALLS:

In 1985, a discovery was made by two English researchers by vapourized the graphite. The modern research shows that the Bucky balls are the clusters of **60 atoms** of Carbon in a molecule. The shape is **spherical**. Unlike diamond and graphite the Bucky balls can be dissolved in organic solvents.

## CHEMICAL PROPERTIES OF CARBON:

### (a) Combustion:

When carbon burns in the excess supply of air ($O_2$), combustion takes place to produce Carbon dioxide ($CO_2$) gas.

$$C_{(s)} - O_{2(g)} \xrightarrow{\text{Excess air}} CO_{2(g)} \qquad \Delta H = -394\ KJ/mol$$

Combustion reaction is highly exothermic due to this characteristic. Carbon in the form of coal, coke or charcoal is usually used as fuel, giving large amount of heat.

When carbon burns in the limited supply of air, incomplete combustion takes place to produce Carbon monoxide (CO) gas.

$$2C_{(s)} + O_{2(g)} \xrightarrow{\text{Limited air}} 2CO_{(g)} \qquad \Delta H = -110\ KJ/mol$$

### (b) Combination (Addition) Reaction:

Carbon combines directly with some non metals and metals (Hydrogen, Sulphur, Calcium, Aluminium, etc.

$$C_{(s)} + 2H_{2(g)} \xrightarrow{\text{high temp}} CH_{4(g)}$$ (Methane)

$$C_{(s)} + 2S_{(s)} \xrightarrow{\text{high temp}} CS_{2(l)}$$ (Carbon disulphide)

$$2C_{(s)} + Ca_{(s)} \xrightarrow{\text{high temp}} CaC_{2(s)}$$ (Calcium carbide)

$$3C_{(s)} + 4Al_{(s)} \xrightarrow{\text{high temp}} Al_4C_{3(s)}$$ (Aluminum carbide)

### (c) As Reducing Agent:

A substance can donate its electron to other is called **Reducing Agent**. Carbon is a powerful reducing agent because it has greater affinity for Oxygen. It reduces many metal or non metal oxides into free elements. These reactions occur at very high temperature.

$$\underset{\text{Ferric oxide}}{Fe_2O_{3(s)}} + 3C_{(s)} \xrightarrow{\text{high temp}} 2Fe_{(s)} + 3CO_{(g)}$$

$$\underset{\text{Zinc oxide}}{2ZnO_{(s)}} + C_{(s)} \xrightarrow{\text{high temp}} 2Zn_{(s)} + CO_{2(g)}$$

$$\underset{\text{Copper oxide}}{2CuO_{(s)}} + C_{(s)} \xrightarrow{\text{high temp}} 2Cu_{(s)} + CO_{2(g)}$$

$$H_2O_{(g)} + C_{(s)} \xrightarrow{\text{high temp}} \underbrace{CO_{(g)} + H_{2(g)}}_{\text{Water gas}}$$

$$CO_{2(g)} + C_{(s)} \xrightarrow{\text{high temp}} 2CO_{(g)}$$

### (d) Reaction with Strong Oxidizing Agents:

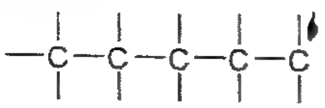
Carbon reacts with strong oxidizing agents like hot concentrated Nitric acid ($HNO_3$) and concentrated Sulphuric acid ($H_2SO_4$) on heating to liberate $CO_2$ gas.

$$C_{(s)} + 4HNO_{3(conc)} \xrightarrow{\text{hot}} CO_{2(g)} + 4NO_{2(g)} + 2H_2O_{(l)}$$

$$C_{(s)} + 2H_2SO_{4(conc)} \xrightarrow{\text{hot}} CO_{2(g)} + 2SO_{2(g)} + 2H_2O_{(l)}$$

## CATENATION:

**Catenation is the ability of Carbon atoms to form long chains and rings compounds.** This property of carbon results in enormous range of compounds of Carbon.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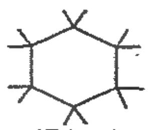
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# SILICON:

## INTRODUCTION:

**Silicon** is a **metalloid**. It belongs to IV-A group in the periodic table. Natural silicates and silica i.e. sand ($SiO_2$) have been known on the earth since ancient times.

## OCCURRENCE OF SILICON:

Silicon does not occur in free state. In the combined state it occurs mainly as Silicon dioxide; $SiO_2$ (Silica) which is present in various forms. Such as Sand, Quartz, Flint, Kieselguhr, etc. They pure crystalline form is quartz and flint (a very hard stone). such as opal, amethyst and onyx (gem-stones). Sand is the less pure form.

Silicon also occurs as complex silicates. Some common natural silicates are:

| S.No. | Name of Silicate | Formula | Uses |
|---|---|---|---|
| 1. | Feldspar | $K_2O.Al_2O_3.6SiO_2$ or $K_2Al_2Si_6O_{16}$ | Ceramics, glass, pottery and abrasive. |
| 2. | Kaolin (China clay) | $Al_2O_3.SiO_2.2H_2O$ | Crockery |
| 3. | Mica | $K_2O.3Al_2O_3.6SiO_2.2H_2O$ or $K_2Al_6Si_6O_{24}$ | Electrical insulator and resistant to high temperature. |
| 4. | Talc (Soapstone) | $3MgO.4SiO_2.H_2O$ or $Mg_3H_2Si_4O_{12}$ | Ceramics, glazed tiles |
| 5. | Asbestos | $CaO.3MgO.4SiO_2$ or $CaMgSi_4O_{12}$ | Heat insulation, Fire proofing material |

## PREPARATION OF SILICON:

(1) Silicon is prepared by heating $SiO_2$ with coke in an electric furnace. This is an industrial method.

$$SiO_{2(s)} + 2C_{(s)} \xrightarrow[\text{Electric furnace}]{\text{heat}} Si_{(s)} + 2CO_{(g)}$$

(2) Silicon is also prepared by heating a mixture of dry sand ($SiO_2$) and Magnesium metal in a fire-clay crucible in the absence of air.

$$\underset{\text{Sand}}{SiO_{2(s)}} + 2Mg_{(s)} \xrightarrow{\text{heat}} Si_{(s)} + 2MgO_{(s)}$$

Dilute hydrochloric acid is then added in the reaction mixture to dissolve unreacted Mg metal and produced MgO as a result an aqueous solution is formed which contains soluble $MgCl_2$ while amorphous silicon remains insoluble.

$$MgO_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2(aq)} + H_2O_{(l)}$$

## PHYSICAL PROPERTIES:

(1) Crystalline Silicon is **grey** in colour, opaque, lustrous and octahedral crystalline solid which specific gravity is 2.5.

(2) Amorphous Silicon is **brown** coloured hygroscopic powder which specific gravity is 2.35.

(3) Silicon is a non-volatile solid. Its melting point is **1410°C** and boiling point is **2600°C.**

(4) It is insoluble in water but it dissolves in hydrofluoric acid (HF).

(5) It is poor conductor of electricity at room temperature but its conductivity increases with the increase in temperature. Due to this characteristic it acts as semi-conductor (metalloid).

## CHEMICAL PROPERTIES:

(1) Silicon dissolves in hot alkali solutions (NaOH or KOH) to form its silicate with the evolution of $H_2$ gas.

$$Si_{(s)} + 2NaOH_{(aq)} + H_2O_{(l)} \xrightarrow{hot} \underset{\text{Sodium silicate}}{Na_2SiO_{3(s)}} + 2H_{2(g)}$$

(2) When Silicon is heated strongly in air, it forms Silicon dioxide i.e. silica ($SiO_2$).

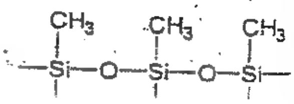
$$Si_{(s)} + O_{2(g)} \xrightarrow{\text{Strong heating}} SiO_{2(s)}$$

## USES (APPLICATIONS):

1. Silicon is used in bronze and steel alloys to increase their tensile strength.
2. Pure Silicon is used in making semi-conductor which has great importance in computers, transistors, solar cells and electronic industries.
3. Silicon is also used in the preparation of refractory materials such as crucible, fire-bricks, etc.

4. It is used for making silicones (rubber like liquids or solids) which are insoluble in water so they are used as lubricants, water-repellent and electrical insulators. They are also used in paints, varnishes and polishes.

5. It is also used to produce Methyl Silicon (a polymer).



(A unit of methyl silicon)

## SILICON DIOXIDE or SILICA ($SiO_2$):

Silicon dioxide is commonly called **Silica** or **Sand.** It occurs naturally in crystalline form which is called **Quartz.**

## PREPARATION:

(i) It is prepared by heating silicon in air or oxygen.

$$Si_{(s)} + O_{2(g)} \xrightarrow{\text{Strong heating}} SiO_{2(s)}$$

(ii) It is also prepared in hydrated form as a gelatinous precipitate by warming sodium silicate ($Na_2SiO_3$) with concentrated Hydrochloric acid (HCl).

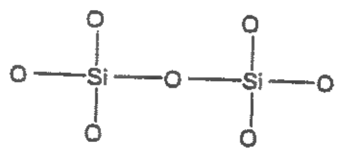
$$Na_2SiO_{3(aq)} + 2HCl_{(conc)} \xrightarrow{\text{Warm}} \underbrace{SiO_2.H_2O_{(s)}}_{\text{Hydrated silica}} + 2NaCl_{(aq)}$$

## PHYSICAL PROPERTIES:

(1) In pure form Silica ($SiO_2$) is colourless crystalline solid.

(2) It is non-volatile solid. Its melting point is about **1500°C** and then molten silica is cooled, it forms glass-like solid, known as **quartz glass.**

(3) It is a **macromolecular** compound with silicon and oxygen atoms linked together covalently in tetrahedral basic units.



($SiO_2$ with tetrahedral units)

## USES (APPLICATIONS):

(1) Sand ($SiO_2$) is widely used in making mortar, cement, concrete and glass.

(2) Fused silica (**quartz glass**) is used in making optical lenses, prisms, glas slab, heat-resisting articles, and fine threads which are used to suspend the parts in electrical instruments.

(3) Powdered quartz is used in the making of Silicon carbide (SiC), Silicon tetra Fluoride ($SiF_4$), Sodium silicate ($Na_2SiO_3$) and silica bricks for lining furnaces.

(4) Kieselguhr ($SiO_2$) absorbs liquids and is used as absorbent of Nitroglycerine (explosive) in making dynamite.

(5) It is also used for making dry antiseptic dressings and silica jel (absorbent pillow) in the antibiotic.

## SODIUM SILICATE or SODA GLASS ($Na_2SiO_3$):

Sodium silicate ($Na_2SiO_3$) is commonly known as soda glass or water glass. Its melting point is 1090°C.

## PREPARATION:

Sodium silicate is prepared by heating strongly silica i.e. sand ($SiO_2$) with sodium carbonate ($Na_2CO_3$) then sodium silicate ($Na_2SiO_3$) a glass like solid is formed.

$$Na_2CO_{3(s)} + SiO_{2(s)} \xrightarrow{\text{strong heating}} Na_2SiO_{3(s)} + CO^{\uparrow}_{2(g)}$$

## USES (APPLICATIONS):

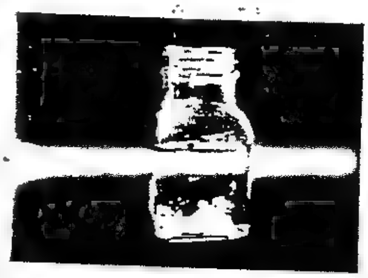
(1) Sodium silicate is used for sizing of paper, fire-proofing material and glue.

(2) It is used as filler in soap industries.

(3) It is used in textile industry.

(4) A dilute solution of Sodium silicate can be used for making chemical garden in the science fare by the students.

## CHEMICAL GARDEN:



Prepare a dilute solution of water glass or soda glass ($Na_2SiO_3$) in a bottle or trough. Add some crystals of coloured salts such as Cobalt Chloride, Nickel Sulphate, Copper Sulphate, Ferric Chloride, etc. Leave the mixture for few hours without touching the trough. After some hours, chemical garden grows the impressions of colourful plants due to the formation of insoluble metal silicates. e.g.

$$Cu^{2+}SO^{2-}_{4(aq)} + Na^{1+}_2SiO^{2-}_3 \longrightarrow \underset{\text{Blue ppt}}{CuSiO_{3(s)}} + Na^{1+}_2SO^{2-}_{4(aq)}$$

## SILICA JEL:

### PREPARATION:

When an acid is added in the solution of water glass or soda glass ($Na_2SiO_3$), it turns into a jelly like substance known as **jel** ($SiO_2.nH_2O$). On complete dehydration of this jel by heating, a hard porous material is obtained known as **silica jel.**

$$Na_2SiO_{3(aq)} + 2HCl_{(conc)} \xrightarrow{\text{Warm}} \underset{\text{Hydrated silica}}{SiO_2.H_2O_{(s)}} + 2NaCl_{(aq)}$$

### USES:

(1) Silica jel is used as good absorbent. It is used to absorb gases and vapours. Small bags of Silica jel are kept in medicine bottles to absorb water vapours in the bottle.

(2) It is also used to recover valuable vapours from industrial effluents.

(3) It is also used in the refining of petroleum.



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# EXERCISE

(1) Fill in the blanks:

(i) Carbon contains **four** electrons in its valence shell and normally forms four **covalent** bonds with other elements.

(ii) Silicon is the second most **abundant** element in the earth's crust after oxygen.

(iii) The molecular formula of sand is **$SiO_2$**.

(iv) The hardest natural substance known is **Diamond.**

(v) **Graphite** is good conductor of electricity.

(vi) The formula of water glass is **$Na_2SiO_3$**

(2) Point out the following statements true or false:

| | | |
|---|---|---|
| (i) | Amorphous form of Silicon is of grey colour. | **False** |
| (ii) | Silicon is used in computers as semi-conductor. | **True** |
| (iii) | The allotropes of Carbon differ in their chemical properties. | **False** |
| (iv) | Silica gel is used as absorbent. | **True** |
| (v) | The driest and hardest type of coal which contains the highest energy value is anthracite. | **True** |
| (vi) | Diamond is a good conductor of electricity. | **False** |
| (vii) | Graphite is used in making lead pencils. | **True** |

(3) Choose the correct answer:

(i) Graphite bars are used in atomic reactors because it:

(a) Soft solid (b) conductor of electricity
(c) More reactive than diamond (d) **Slows down the neutrons**

(ii) Diamond is used as abrasive because it is:

(a) **Hard** (b) Soft
(c) Cubic (d) Bad conductor of electricity

(iii) Silicon is most abundantly found in natures as:

(a) **Silica ($SiO_2$)** (b) Silicon Carbide (SiC)
(c) Sodium Silicate (d) Calcium Silicate

(iv) China clay is used in making of:

(a) Glass (b) Electrical insulator
(c) Ceramics (d) **Crockeries**

(v) Fused Silica which is also known as quartz glass is used for making:

(a) Concrete or cement (b) Soft
(c) **Optical lenses and prisms** (d) Absorbent

(vi) Melting point of Sodium silicate is:

(a) 1100°C (b) **1090°C**
(c) 1410°C (d) 990°C

SESSION
2016-2017

# CLASS-IX

# CHEMISTRY

## Chapter # 13

## NITROGEN AND OXYGEN

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# NITROGEN AND OXYGEN 13

## INTRODUCTION:

**Nitrogen** was discovered in **1772** by **Daniel Rutherford.** It is the $10^{th}$ most abundant element found in earth's crust. Nitrogen belongs to V-A group in the periodic table. Nitrogen is a non-metal. It is found in gaseous state with diatomic molecular form [illegible] major building blocks of living things, in the form of DNA, RNA, etc.

**Oxygen** was discovered in **1774** by **Priestley.** Oxygen belongs to VI-A group in the periodic table. Oxygen is a non-metal. It is found in gaseous state with diatomic molecular form ($O_2$) in the air. Oxygen is one of the essential gases for life. It helps respiration.

| Name | $1^{st}$ shell | $2^{nd}$ shell | $3^{rd}$ shell | $4^{th}$ shell |
|---|---|---|---|---|
| Nitrogen( $_7N$ ) | $K^2$ | $L^5$ | - | - |
| Oxygen ( $_8O$ ) | $K^2$ | $L^6$ | - | - |

## OCCURRENCE:

| NITROGEN | OXYGEN |
|---|---|
| **Free State:** | **Free State:** |
| Nitrogen occurs in the free state as $N_2$ gas in air up to 78% by volume. | Oxygen occurs in the free state as $O_2$ gas in air up to 21% by volume. |
| Free Nitrogen in air is important because it dilutes the Oxygen to the point where combustion, respiration and oxidation process are reasonably slow. | Free Oxygen in air is important because it helps combustion, respiration and oxidation process naturally and with reasonably fast. |
| **Combined State (Compound Form):** | **Combined State (Compound Form):** |
| Nitrogen occurs in the earth crust as Nitrates of Sodium, Calcium and Potassium as well as Ammonium salts such as ammonium sulphate, $(NH_4)_2SO_4$. | Oxygen occurs in the earth crust as water in the oceans rivers, lakes, etc and the air. It is found about 88.9% by mass in water ($H_2O$). Water is the most abundant compound on earth. |
| Nitrogen is also found in organic matter such as proteins, urea and vitamin B-compounds. Thus the Nitrogen compounds must be present in animal diets and plants fertilizers for the growth, repair and maintenance. Proteins that occupy an essential place in the structure of all living things. | Oxygen is also found in inorganic matter such as Silica ($SiO_2$), Silicates, Carbonates and Oxides of both metals and non-metals, thus the Oxygen compounds must be present in rocks, clays and sand. Even the human body is made up of about two third (2/3) by mass of oxygen. |

## PREPARATION OF NITROGEN:

### (a) IN LABORATORY:

Nitrogen is prepared by thermal decomposition of Ammonium Nitrite. Ammonium Nitrite is obtained by reacting Ammonium Chloride with Sodium Nitrite.

**Preparation of $N_2$**

$$NH_4NO_{2(s)} \xrightarrow{\text{cal}} N_{2(g)} + 2H_2O_{(l)}$$

**Formation of Ammonium Nitrite**

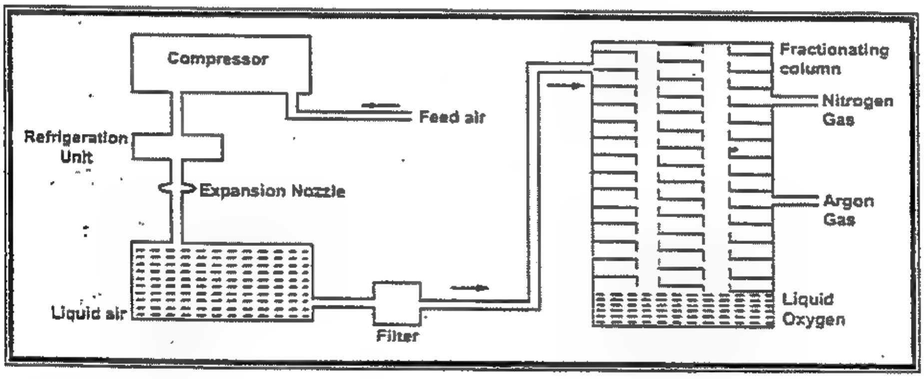
$$NH_4Cl_{(s)} + NaNO_{2(s)} \longrightarrow \underset{\text{Ammonium nitrite}}{NH_4NO_{2(s)}} + NaCl_{(s)}$$

### (b) IN INDUSTRY:

In the industry, Nitrogen and Oxygen is prepared by the fractional distillation of liquid air.

Air is passed through caustic soda (NaOH) to remove $CO_2$ and other acidic impurities present in air. Now it is compressed under very high pressure and then cooled down. The process of compression and expansion are repeated again and again due to this temperature falls upto −200°C at which air becomes liquid.

The liquid air contains nitrogen, oxygen and argon. Liquid air is passed through fractionating column where at −196°C, Nitrogen boils and can be removed from the top of the column similarly Argon boils at −185.7°C and then is removed from the middle of the column while liquid oxygen is collected from the bottom of the column at −183°C.




## PHYSICAL PROPERTIES:

(1) Nitrogen ($N_2$) is a colourless, odourless and tasteless gas.

(2) It is slightly lighter than air.

(3) Its boiling point (liquefies) is − 196°C, while melting point (solidifies) is − 210°C.

(4) The bond dissociation energy of $N_2$ ($N \equiv N$) is 941 KJ/mol.

(5) It is slightly soluble in water only about 2% by volume at room temperature.

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## CHEMICAL PROPERTIES:

### (a) With hydrogen:

Nitrogen combines with hydrogen at **450°C** to form ammonia gas ($NH_3$).

$$N_{2(g)} + 3H_{2(g)} \xrightleftharpoons[Fe_2O_3,Al_2O_3]{450°C/200\text{-}250atm} 2NH_{3(g)}$$

### (b) With oxygen:

Nitrogen combines with oxygen at **2000°C** to from nitric oxide (NO).

$$N_{2(g)} + O_{2(g)} \xrightarrow{2000°C} 2NO_{(g)}$$

### (c) With magnesium:

Nitrogen combines with magnesium directly on heating to red hot to form magnesium nitride.

$$3Mg_{(s)} + N_{2(g)} \xrightarrow{red\ hot} Mg_3N_{2(s)}$$

## COMPOUNDS OF NITROGEN (AMMONIA AND NITRIC ACID):

## (1) AMMONIA GAS ($NH_3$):

Ammonia is a very important chemical in industry. Following are the methods to prepare ammonia gas.

## PREPARATION OF AMMONIA GAS:

### (a) IN LABORATORY:

Ammonia is prepared by heating Ammonium Chloride [$NH_4Cl$] with slaked lime [$Ca(OH)_2$] calcium hydroxide. Ammonium chloride and powdered calcium hydroxide is taken in the flat bottom flask. An inverted delivery tube is attached with the flask through cork. This mixture is heated then ammonia gas is collected downward displacement of air.

$$2NH_4Cl_{(s)} + Ca(OH)_{2(s)} \xrightarrow{heat} CaCl_{2(s)} + 2H_2O_{(l)} + \underset{ammonia}{2NH_{3(g)}}$$

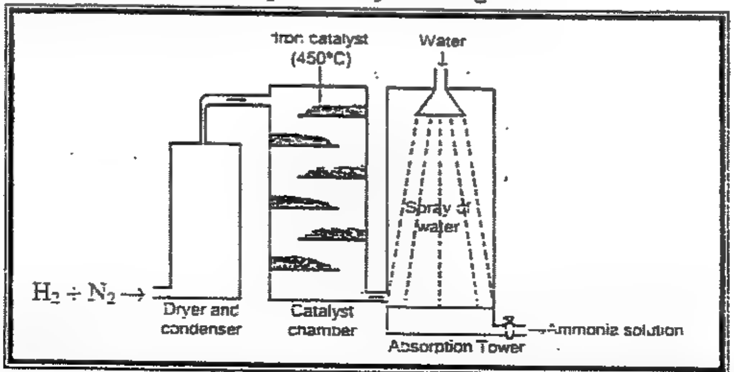
### (b) IN INDUSTRY:

### Haber Bosch Process:

In this process, a mixture of pure nitrogen and hydrogen in the ratio 1:3 by volumes is allowed to react. The basic problem in ammonia synthesis is that it is a reversible reaction and can be described as:

$$N_{2(g)} + 3H_{2(g)} \xrightleftharpoons[Fe_2O_3.Al_2O_3]{400\text{–}450°C/200\text{-}250\ atm} 2NH_{3(g)} \qquad \Delta H = -92\ KJ/mol.$$

For maximum yield of Ammonia, the required condition of temperature should be 400–450°C and pressure should be 200-250 atmosphere while a mixture of catalyst $Fe_2O_3$ (Ferric oxide) with small amount of $Al_2O_3$ are required. At optimum conditions Ammonia gas is obtained which is liquefied by cooling.



## PHYSICAL PROPERTIES:

(1) Ammonia is a colourless gas with pungent smell.
(2) Its solution is alkaline as it turns red litmus blue.
(3) It is highly soluble in water and its solution is called aqueous ammonia.
(4) In large quantity, Ammonia is poisonous because of its effect on respiratory system.

## CHEMICAL PROPERTIES:

### (1) Reaction With Water:

Ammonia reacts with water to form ammonium hydroxide.

$$NH_{3(g)} + H_2O_{(l)} \longrightarrow NH_4OH_{(aq)}$$

### (2) Reaction With Oxygen:

In the presence of heated Platinum (Pt) catalyst, ammonia reacts with excess of air (oxygen) to produce Nitric oxide (NO) gas.

$$4NH_{3(g)} + 5O_{2(g)} \xrightarrow[600^\circ C]{Pt} 4NO_{(g)} + 6H_2O_{(g)} \quad \Delta H = -95KJ/mol$$

### (3) Reaction With Acids:

Since ammonia is a base, so it reacts with acids to form ammonium salts.

$$2NH_{3(g)} + H_2SO_{4(aq)} \longrightarrow \underset{\text{Ammonium sulphate}}{(NH_4)_2SO_{4(aq)}}$$

$$NH_{3(g)} + HCl_{(aq)} \longrightarrow NH_4Cl_{(s)}$$

### (4) Reaction With Chlorine ($Cl_2$):

When ammonia reacts with chlorine, white fumes of ammonium chloride [$NH_4Cl$] and nitrogen gas [$N_2$] are formed.

$$8NH_{3(g)} + 3Cl_{2(g)} \longrightarrow \underset{\text{Ammonium chloride}}{6NH_4Cl_{(s)}} + N_{2(g)}$$

This reaction takes place in two steps:

(a) $2NH_{3(g)} + 3Cl_{2(g)} \longrightarrow N_{2(g)} + 6HCl_{(g)}$

(b) $6NH_{3(g)} + 6HCl_{(g)} \longrightarrow \underset{\text{White fumes}}{6NH_4Cl_{(s)}}$

### (5) As Reducing Agent:

Ammonia can act as reducing agent. However it reduces heated copper oxide (CuO) to free copper metal with the evolution of $N_2$ gas and water.

$$3CuO_{(s)} + 2NH_{3(g)} \xrightarrow{heat} 3Cu_{(s)} + N_{2(g)} + 3H_2O_{(l)}$$

### (6) Reaction With Carbon Dioxide ($CO_2$):

Ammonia reacts with $CO_2$ at high temperature about 150°C under high pressure to produce Urea [$(NH_2)_2CO$], which is an important fertilizer.

$$2NH_{3(g)} + CO_{2(g)} \xrightarrow[\text{High pressure}]{150^\circ C} \underset{\text{Urea}}{(NH_2)_2CO_{(s)}} + H_2O_{(l)}$$

## USES:

(1) Aqueous ammonia is used in laboratories as weak basic solution.
(2) It is used as solvent in laundries for removing grease and oil stains.
(3) Liquid ammonia is used as cooling agent in some refrigerators.
(4) The biggest use of ammonia is in the manufacture of nitrogenous fertilizers, like urea, ammonium sulphate, ammonium nitrate, ammonium phosphate, etc.

## (2) NITRIC ACID ($HNO_3$):

Nitric acid is a very important acid which is used extensively in the laboratories and in industries. It was first prepared by **Glauber in 1685** from sulphuric acid and Potassium Nitrate. In early ages, it is called **Aqua Fortis (strong water)** because it was used for separating gold from silver, silver being soluble in this acid while gold is insoluble.

## PREPARATION OF NITRIC ACID:

### (a) IN LABORATORY:

Nitric acid is prepared by heating solid Potassium Nitrate ($KNO_3$) with conc. Sulphuric acid ($H_2SO_4$)

$$\underset{}{KNO_{3(s)}} + H_2SO_{4(aq)} \xrightarrow{heat} \underset{\text{Potassium hydrogen sulphate}}{KHSO_{4(aq)}} + \underset{\text{Nitric acid}}{HNO_{3(g)}}$$

### (b) IN INDUSTRY (OSTWALD'S METHOD):

Nitric acid is manufactured on large scale by the catalytic oxidation of ammonia by Ostwald's method.

**STEP# 1:**

In this step, Ammonia gas is allowed to react with excess of air in presence of platinum catalyst at **600°C** to produce nitric oxide (NO) gas and steam in the catalytic chamber. The catalyst is used in the form of gauze.

$$4NH_{3(g)} + 5O_{2(g)} \xrightarrow[600°C]{Pt} 4NO_{(g)} + 6H_2O_{(g)} \quad \Delta H = -95KJ/mol$$

**STEP# 2:**

Since the reaction is exothermic, the temperature of chamber is increased so the gaseous mixture is passed through coolers untill temperature is reached about **150°C**.

Nitric oxide (NO) is then mixed with excess of air in oxidation chamber to produce Nitrogen dioxide ($NO_2$).

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$$

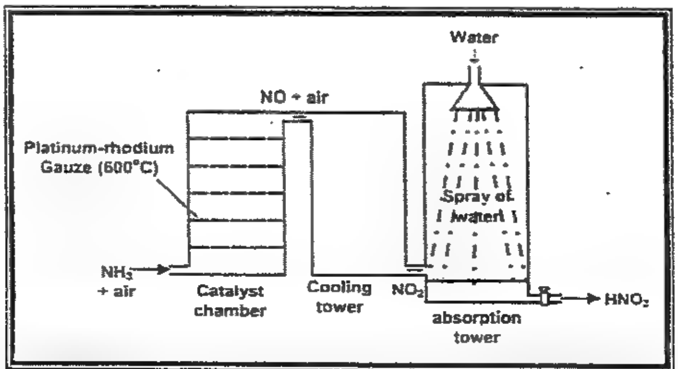
**STEP# 3:**

Nitrogen dioxide ($NO_2$) is directly dissolved in water to produce Nitric acid, liberating Nitric oxide (NO) gas in the absorption chamber. Nitric oxide gas is sent back to the oxidation chamber.

$$3NO_{2(g)} + H_2O_{(l)} \longrightarrow 2HNO_{3(aq)} + NO_{(g)}$$

**STEP# 4:**

Nitric acid obtained from this process is 68% concentrated which can be concentrated further by passing over concentrated $H_2SO_4$.



## PHYSICAL PROPERTIES:

(1) Pure Nitric acid is a colourless fuming liquid with sharp chocking smell. It has sour taste.

(2) Its boiling point is **83°C** while its freezing point is **- 41.6°C**.

(3) The density of pure nitric acid is $1.52 g/cm^3$.

(4) It is highly soluble in water.

(5) Concentrated nitric acid decomposes [illegible] Nitrogen dioxide ($NO_2$).

$$4HNO_{3(conc)} \xrightarrow{heat} 4NO_{2(g)} + O_{2(g)} + 2H_2O_{(l)}$$

The yellow colour of nitric acid is due to dissolved nitrogen dioxide ($NO_2$) gas.

## CHEMICAL PROPERTIES:

### (1) As an Acid:

**(a) Reaction with water:**

Nitric acid is a strong monobasic acid in its aqueous solution ionizes completely in water as:

$$HNO_3 + H_2O \rightleftharpoons \underbrace{H_3O^+}_{\text{Hydronium ion}} + NO_3^-$$

**(b) Reaction with Alkali:**

Nitric acid reacts with alkalies to form salt and water, metal oxides and metal carbonates to form nitrate salt and water.

$$HNO_{3(aq)} + KOH_{(aq)} \longrightarrow KNO_{3(aq)} + H_2O_{(l)}$$

**(c) Reaction with Metals:**

Nitric acid reacts with metals to form salt and hydrogen gas is liberated.

$$Mg_{(s)} + 2HNO_{3(aq)} \longrightarrow Mg(NO_3)_{2(aq)} + H_{2(g)}$$

**(d) Reaction with Metal Oxide:**

Nitric acid reacts with metals to form salt and water.

$$MgO_{(s)} + 2HNO_{3(aq)} \longrightarrow Mg(NO_3)_{2(aq)} + H_2O_{(l)}$$

**(e) Reaction with Metal Carbonate or Bicarbonate:**

Nitric acid reacts with metal carbonate or bicarbonate to form nitrate salt and water while carbon dioxide gas is liberated.

$$Na_2CO_{3(s)} + 2HNO_{3(aq)} \longrightarrow 2NaNO_{3(aq)} + CO_{2(g)} + H_2O_{(l)}$$

$$NaHCO_{3(s)} + HNO_{3(aq)} \longrightarrow NaNO_{3(aq)} + CO_{2(g)} + H_2O_{(l)}$$

## (2) As an Oxidizing Agent:

Nitric acid acts as a powerful oxidizing agent because it is an electron acceptor and has nitrogen at its highest oxidation state (+5).

### (a) Reaction with Non-Metals:

Hot and **Concentrated Nitric acid** reacts with many non-metals:

**with Carbon:** Carbon reacts with nitric acid to liberate $CO_2$ gas on heating

$$C_{(s)} + 4HNO_{3(conc)} \longrightarrow CO_{2(g)} + 4NO_{2(g)} + 2H_2O_{(l)}$$

**with Silicon:** Silicon (Si) reacts with nitric acid to liberate $NO_2$ gas on heating.

$$Si_{(s)} + 4HNO_{3(conc)} \longrightarrow SiO_{2(s)} + 4NO_{2(g)} + 2H_2O_{(l)}$$

**with Sulphur:** Sulphur reacts with nitric acid to liberate $SO_2$ gas on heating.

$$Si_{(s)} + 4HNO_{3(conc)} \longrightarrow SiO_{2(s)} + 4NO_{2(g)} + 2H_2O_{(l)}$$

**with Phosphorous:** Phosphorous reacts with nitric acid to liberate $NO_2$ gas and **phosphoric acid** is formed on heating.

$$P_{(s)} + 5HNO_{3(conc)} \longrightarrow \underset{\text{Phosphoric acid}}{H_3PO_{4(aq)}} + 5NO_{2(g)} + H_2O_{(l)}$$

**with Iodine:** Iodine reacts with nitric acid to liberate $NO_2$ gas and **hydrogen iodate** is formed on heating.

$$I_{2(s)} + 10HNO_{3(conc)} \longrightarrow 2HIO_{3(aq)} + 10NO_{2(g)} + 4H_2O_{(l)}$$

### (b) Reaction with Metals:

Concentrated as well as dilute nitric acid reacts with many less electropositive metals to liberate Nitrogen dioxide ($NO_2$) and Nitric oxide (NO).

**with Copper:** Copper (Cu) reacts with Concentrated nitric acid to liberate $NO_2$ gas.

$$Cu_{(s)} + 4HNO_{3(conc)} \xrightarrow{hot} Cu(NO_3)_{2(aq)} + 2NO_{2(g)} + 2H_2O_{(l)}$$

Copper (Cu) reacts with dilute nitric acid to liberate NO gas.

$$3Cu_{(s)} + 8HNO_{3(dil)} \longrightarrow 3Cu(NO_3)_{2(aq)} + 2NO_{(g)} + 4H_2O_{(l)}$$

**with Lead:** Lead (Pb) reacts with Concentrated nitric acid to liberate $NO_2$ gas.

$$Pb_{(s)} + 4HNO_{3(conc)} \xrightarrow{hot} Pb(NO_3)_{2(aq)} + 2NO_{2(g)} + 2H_2O_{(l)}$$

Lead (Pb) reacts with dilute nitric acid to liberate NO gas.

$$3Pb_{(s)} + 8HNO_{3(dil)} \longrightarrow 3Pb(NO_3)_{2(aq)} + 2NO_{(g)} + 4H_2O_{(l)}$$

**with Zinc:** Zinc (Zn) reacts with Concentrated nitric acid to liberate $NO_2$ gas.

$$Zn_{(s)} + 4HNO_{3(conc)} \xrightarrow{hot} Zn(NO_3)_{2(aq)} + 2NO_{2(g)} + 2H_2O_{(l)}$$

Zinc (Zn) reacts with dilute nitric acid to form **ammonium nitrate.**

$$4Zn_{(s)} + 10HNO_{3(dil)} \longrightarrow 4Zn(NO_3)_{2(aq)} + NH_4NO_{3(aq)} + 3H_2O_{(l)}$$

### (c) Reaction with Reducing Agents:

Nitric acid which is a strong oxidizing agent also undergoes redox reactions with some common reducing agents like, $H_2S$, $SO_2$, etc.

**with $H_2S$:** Conc. nitric acid oxidizes $H_2S$ to **sulphur** while it liberates $NO_2$ gas.

$$H_2S_{(g)} + 2HNO_{3(conc)} \longrightarrow S_{(s)} + 2NO_{2(g)} + 2H_2O_{(l)}$$

**with $SO_2$ :** Conc. nitric acid oxidizes $SO_2$ (Sulphur dioxide) to $H_2SO_4$ while it liberates $NO_2$ gas.

$$SO_{2(g)} + 2HNO_{3(conc)} \longrightarrow \underset{\text{Sulphuric acid}}{H_2SO_{4(aq)}} + 2NO_{2(g)}$$

## AQUA REGIA:

The noble metals like gold, platinum which are not soluble in concentrated nitric acid. However they are dissolved in a mixture of conc. $HNO_3$ and conc. $HCl$ taken in the ratio of 1:3. This mixture is called **Aqua Regia or Royal Water.**

Aqua regia dissolves gold due to liberation of nascent chlorine which reacts with gold to form soluble gold chloride.

$$HNO_{3(conc)} + 3HCl_{(conc)} \longrightarrow \underset{\text{Nitrosyl chloride}}{NOCl_{(aq)}} + 2H_2O_{(l)} + \underset{\text{Nascent or atomic chlorine}}{2[Cl]_{(g)}}$$

$$NOCl_{(g)} \longrightarrow NO_{(g)} + [Cl]_{(g)}$$

$$Au_{(s)} + 3Cl_{(g)} \longrightarrow \underset{\text{Gold chloride}}{AuCl_{3(aq)}}$$

## USES:

(1) It is used as in laboratory as a strong acid.

(2) Large amount of nitric acid is used in the manufacture of fertilizers. Such as $NH_4NO_3$, $NaNO_3$, $KNO_3$, etc.

(3) It is used in the manufacture of cellulose, lacquers and smokeless gun powder.

(4) It is used in the manufacture of dyes and explosives such as nitroglycerol and trinitrotoluene (T.N.T) which are powerful explosives.

(5) It is used as a powerful oxidizing agent in the production of important polymers like nylon and terylene.

(6) It is used in the formation of aqua regia which dissolves noble metals and it is also used for **etching** (designing on copper plates).

## INTRODUCTION:

Oxygen was discovered in **1774** by **Priestley.** Oxygen belongs to VI-A group in the periodic table. Oxygen is a non-metal. It is found in gaseous state with diatomic molecular form ($O_2$) in the air. Oxygen is one of the essential gas for life. It helps respiration.

| Name | $1^{st}$ shell | $2^{nd}$ shell | $3^{rd}$ shell | $4^{th}$ shell |
|---|---|---|---|---|
| Oxygen ( $_8O$ ) | $K^2$ | $L^6$ | - | - |

## PREPARATION OF OXYGEN:

### (a) IN LABORATORY:

Oxygen is prepared by thermal decomposition of Potassium Chlorate ($KClO_3$) in presence of a catalyst Manganese dioxide ($MnO_2$).

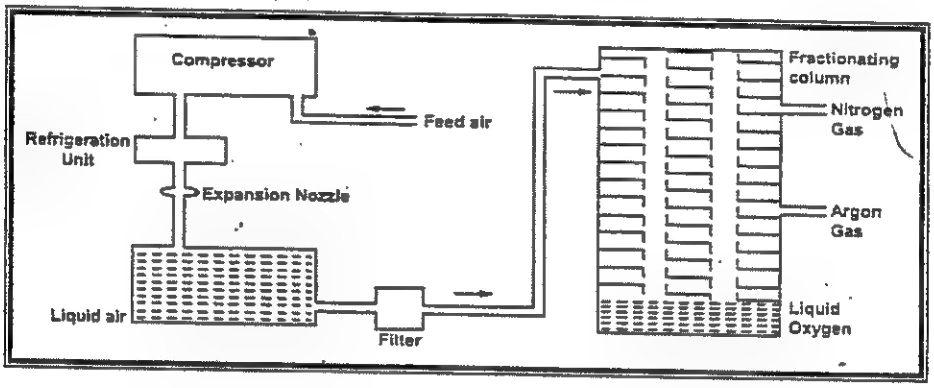
$$2KClO_{3(s)} \xrightarrow{\text{heat}/MnO_2} 2KCl_{(s)} + 3O_{2(g)}$$

## (b) IN INDUSTRY:

In the industry, Nitrogen and Oxygen is prepared by the fractional distillation of liquid air.

Air is passed through caustic soda (NaOH) to remove $CO_2$ and other acidic impurities present in air. Now it is compressed under very high pressure and then cooled down. The process of compression and expansion are repeated again and again due to which temperature falls upto –200 °C at which air becomes liquid.

The liquid air contains nitrogen, oxygen and argon. Liquid air is passed through fractionating column where at **–196°C**, Nitrogen boils and can be removed from the top of the column similarly Argon boils at **–185.7°C** and then is removed from the middle of the column while liquid oxygen is collected from the bottom of the column at –183°C.




## PHYSICAL PROPERTIES:

(1) Oxygen ($O_2$) is a colourless, odourless and tasteless gas.
(2) It is 1.1 times heavier than air.
(3) It liquefies (boiling point) at **–183°C** and solidifies (melting point) at –225°C.
(4) The bond dissociation energy of $O_2$ ($O = O$) is **498 KJ/mol**
(5) It is slightly soluble in water only about 2% by volume at room temperature.

## CHEMICAL PROPERTIES:

Oxygen reacts with metals, non-metals and other compounds directly. The binary compounds of oxygen are known as **oxides.**

## OXIDES:

The binary compounds of oxygen with metals and non metals are called Oxides.

**e.g** CaO, $Fe_2O_3$, $CO_2$, $H_2O$, etc.

## Classification of Oxides:

On the basis of oxidation state (valence number) of Oxygen, oxides are classified into several groups like

(i) Normal Oxides
(ii) Peroxides
(iii) Super Oxides
(iv) Sub Oxides

## (1) NORMAL OXIDES:

Normal oxides are those oxides in which oxygen shows -2 oxidation state (valence number)

Normal oxides are further classified into four types on the basis of their chemical characteristics.

(a) Basic oxides (b) Acidic oxides

## (a) BASIC OXIDES:

The normal oxides of metals are the examples of basic oxides.

e.g. $4Na_{(s)} + O_{2(g)} \longrightarrow 2Na_2O_{(s)}$

$2Ca_{(s)} + O_{2(g)} \longrightarrow 2CaO_{(s)}$

These oxides react with water to form their bases which turn red litmus blue.

$Na_2O_{(s)} + H_2O_{(l)} \longrightarrow 2NaOH_{(aq)}$

$CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)}$

These oxides react with acids to form salts and water.

$Na_2O_{(s)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + H_2O_{(l)}$

$CaO_{(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2\,(aq)} + H_2O_{(l)}$

## (b) ACIDIC OXIDES:

The normal oxides of non-metals are the examples of acidic oxides.

e.g. $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$

$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$

These oxides react with water to form acids which turn blue litmus red.

$CO_{2(g)} + H_2O_{(l)} \longrightarrow H_2CO_{3(aq)}$ **(Carbonic acid)**

$SO_{2(g)} + H_2O_{(l)} \longrightarrow H_2SO_{3(aq)}$ **(Sulphurous acid)**

These oxides react with base (alkali) to form salts and water.

$CO_{2(s)} + 2NaOH_{(aq)} \longrightarrow Na_2CO_{3(aq)} + H_2O_{(l)}$

## (c) AMPHOTERIC OXIDES:

The normal oxides of less electro-positive metals (Aluminium, Zinc, Iron, Tin) are the examples of Amphoteric oxides. They react with acid and base to form salt and water.

e.g. $4Al_{(s)} + 3O_{2(g)} \longrightarrow 2Al_2O_{3(s)}$

$2Zn_{(s)} + O_{2(g)} \longrightarrow 2ZnO_{(s)}$

Amphoteric oxides react with acids to form salt and water.

$Al_2O_{3(s)} + 6HCl_{(aq)} \longrightarrow 2AlCl_{3(aq)} + 3H_2O_{(l)}$

$ZnO_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_2O_{(l)}$

Amphoteric oxides react with alkalis to form salts and water.

$Al_2O_{3(s)} + 2NaOH_{(aq)} \longrightarrow \underset{\text{Sodium aluminate}}{2NaAlO_{2(aq)}} + 3H_2O_{(l)}$

$ZnO_{(s)} + 2NaOH_{(aq)} \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_{2(aq)}} + H_2O_{(l)}$

### (d) NEUTRAL OXIDES:

Neutral oxides are neither acidic nor basic. They are neutral to litmus in aqueous solutions.

e.g. Water ($H_2O$), Nitric oxide ($NO$), Nitrous oxide ($N_2O$) and Carbon monoxide ($CO$).

### (2) PEROXIDES:

Peroxides are those oxides in which ...

These oxides contain higher proportion of Oxygen as compared to normal oxides.

e.g. Sodium peroxide ($Na_2O_2$), Barium peroxide ($BaO_2$) and also hydrogen peroxide ($H_2O_2$).

### (3) SUPER OXIDES:

Super oxides are those oxides in which oxygen shows $-\frac{1}{2}$ oxidation state (valence number).

Potassium, Rubidium and Caesium (from IA group) form Super oxides. They contain more oxygen than peroxides.

e.g. Potassium super oxide ($KO_2$), Rubidium superoxide ($RbO_2$) and Caesium superoxide ($CsO_2$).

### (4) SUBOXIDES:

Suboxides have less quantity of oxygen than the normal oxides. They are unstable. Very few suboxides are known.

e.g. Carbon suboxide ($C_3O_2$).

## HYDROGEN PEROXIDE or OXYGENATED WATER ($H_2O_2$):

### Introduction:

Hydrogen peroxide ($H_2O_2$) contains one more oxygen atom than water ($H_2O$) so it is also called **Oxygenated water.**

### PREPARATION:

### (a) IN LABORATORY:

Hydrogen peroxide is prepared by the action of dilute sulphuric acid on barium peroxide ($BaO_2$). Barium sulphate is insoluble and can be easily removed by filtration and pure $H_2O_2$ is obtained.

$$H_2SO_{4(aq)} + BaO_{2(s)} \rightarrow BaSO_{4(s)} + H_2O_{2(aq)}$$

### (b) IN INDUSTRY:

Hydrogen peroxide is usually manufactured by the oxidation of isopropyl alcohol (Propan-2-ol) with oxygen under reduced pressure.

$$\underset{\text{Isopropyl alcohol}}{CH_3-\underset{\displaystyle OH}{\underset{|}{CH}}-CH_{3(l)}} + O_{2(g)} \longrightarrow \underset{\text{hydrogen peroxide}}{H_2O_{2(l)}} + \underset{\text{acetone}}{CH_3-\overset{\displaystyle O}{\overset{||}{C}}-CH_{3(l)}}$$

## PHYSICAL PROPERTIES:

(1) It is pale blue liquid with sour taste.
(2) It turns blue litmus red.
(3) It mixes with water to give solution which is slightly acidic.
(4) It melts at -1°C and boils at 150°C but it decomposed on it.

## CHEMICAL PROPERTIES:

### (1) Decomposition:

Hydrogen peroxide is heated in presence of Manganese dioxide (MnO₂) then Oxygen gas is produced with water.

$$2H_2O_{2(l)} \xrightarrow{\text{exposure}} 2H_2O_{(l)} + O_{2(g)} + \text{heat}$$

### (2) As Oxidizing Agent:

Hydrogen peroxide is a strong oxidizing agent because it can readily donate oxygen or accept electrons.

$$H_2O_{2(l)} \longrightarrow H_2O_{(l)} + \underset{\text{Atomic oxygen}}{[O]} \quad \textbf{(donor of oxygen)}$$

$$H_2O_{2(l)} + 2H^+ + 2e^- \longrightarrow 2H_2O_{(l)} \quad \textbf{(acceptor of electron)}$$

$$2KI_{(aq)} + H_2O_2 + H_2SO_{4(aq)} \longrightarrow K_2SO_{4(aq)} + 2H_2O_{(l)} + I_{2(s)}$$

$$H_2S_{(g)} + H_2O_{2(aq)} \longrightarrow \underset{\text{Yellow ppt}}{S_{(s)}} + 2H_2O_{(l)}$$

### (3) As Reducing Agent:

It reacts with more powerful oxidizing agents then oxygen gas is releazed so it can also act as a reducing agent.

$$2KMnO_{4(aq)} + 3H_2SO_{4(aq)} + 5H_2O_{2(aq)} \rightarrow K_2SO_{4(aq)} + 2MnSO_{4(aq)} + 8H_2O_{(l)} + 5O_{2(g)}$$

$$\underset{\text{Oxidizing agent}}{Cl_{2(g)}} + \underset{\text{Reducing agent}}{H_2O_{2(aq)}} \rightarrow 2HCl_{(aq)} + O_{2(g)}$$

## USES:

(1) Hydrogen peroxide is used as a **mild antiseptic** in mouth wash as well as cleaning wounds.

(2) Hydrogen peroxide is used as **bleaching agent** in bleaching delicate materials like silk, wool, feathers and human hairs which are usually damaged by other bleaching agents like chlorine, sulphur dioxide etc. it removes unwanted colour from fabrics, hair or other materials.

(3) Liquid $H_2O_2$ is used for **restoring paintings**. Lead paints containing lead carbonate ($PbCO_3$) when exposed to atmosphere blacken due to exposure to atmospheric $H_2S$. $PbCO_3$ is converted into lead sulphide, ($PbS$). The treatment with $H_2O_2$ oxidizes lead sulphide into $PbSO_4$, thus the white colour is restored.

(4) Liquid $H_2O_2$ is use **for providing oxygen** for burning fuel in space rockets. It is also used for burning diesel oil in engines of submarines.

(5) It is used in the **preparation of compounds** like sodium chlorate ($NaClO_3$) and some organic peroxides which are used for polymerizations.

# OXIDATION and REDUCTION:

## (1) OXIDATION:

Oxidation can be defined as:

(a) Addition of oxygen in a substance (b) Removal of Hydrogen

(c) Loss of electrons from a substance

### (a) Oxidation as addition of oxygen:

... oxygen combines with other elements or substances.

$$4Fe_{(s)} + 3O_{2(g)} \longrightarrow \underset{\text{Ferric oxide}}{2Fe_2O_{3(s)}}$$

$$C_{(s)} + O_{2(g)} \longrightarrow \underset{\text{Carbon dioxide}}{CO_{2(g)}}$$

$$2NO_{(g)} + O_{2(g)} \longrightarrow \underset{\text{Nitirogen peroxide or nitrogen dioxide}}{2NO_{2(g)}}$$

### (b) Oxidation as removal of hydrogen:

A process in which the removal of hydrogen occurs from a compound.

$$MnO_{2(s)} + 4HCl_{(aq)} \longrightarrow MnCl_{2(aq)} + Cl_{2(g)} + 2H_2O_{(l)}$$

### (c) Oxidation as removal or loss of electrons:

A process in which loss or removal of electron from a substance takes place.

$$Na_{(s)} \longrightarrow Na^+ + 1e^-$$

$$Mg_{(s)} \longrightarrow Mg^{2+} + 2e^-$$

$$Cl^-_{(aq)} \longrightarrow Cl + 1e^-$$

## (2) REDUCTION:

Reduction can be defined as:

(a) Removal of oxygen from a substance (b) Addition of Hydrogen

(c) Gain of electrons by a substance

### (a) Reduction as Removal of oxygen:

A process in which the removal of oxygen from substances is taken place.

$$CuO_{(s)} + C_{(s)} \rightarrow Cu_{(s)} + CO_{(g)}$$

Reduction

### (b) Reduction as Addition of $H_2$ (Hydrogen):

A process in which the addition of hydrogen takes place.

$$H_2S_{(g)} + Cl_{2(g)} \rightarrow S_{(s)} + 2HCl_{(g)}$$

Reduction

### (c) Reduction as Gain of electrons:

A process in which gain of electron takes place.

$$Zn^{+2}_{(aq)} + 2e^- \longrightarrow Zn_{(s)}$$

$$Cl_{(g)} + 1e^- \longrightarrow Cl^-_{(aq)}$$

## REDUCING AGENTS:

A substance which donates or loses electron(s) and oxidizes itself is called reducing agent. Oxidation takes place in presence of reducing agent.

e.g. All metals, Carbon, $H_2S$, $NH_3$, $H_2O_2$ are the examples of reducing agents.

## OXIDIZING AGENTS:

A substance which accepts or gains electron(s) and reduces itself is called oxidizing agent. Reduction takes place in presence of oxidizing agent.

e.g. Non-metals, acids, $O_2$, $Cl_2$, NO, etc. are the examples of oxidizing agents.

$$4NH_{3(g)} + 6NO_{(g)} \longrightarrow 5N_{2(g)} + 6H_2O_{(l)}$$

In this reaction $NH_3$ oxidizes to $N_2$ (oxidation-removal of hydrogen) so it is a reducing agent ($NH_3$). NO reduce to $N_2$ (Reduction-removal of oxygen) so it is an oxidizing agent.

## REDOX REACTIONS:

When oxidation and reduction reactions take place simultaneously then the reactions are called ***Redox Reactions***.

$$\underset{\substack{\text{Reducing agent} \\ \text{Oxidation takes place}}}{H_2S_{(g)}} + \underset{\substack{\text{Oxidizing agent} \\ \text{Reduction takes place}}}{Cl_{2(g)}} \longrightarrow S_{(s)} + 2HCl_{(g)}$$

## OZONE:

Ozone is a pale-blue poisonous gas with a sharp, irritating odour. It is an allotropic form of oxygen with molecular formula $O_3$. Ozone was first discovered by **Schonbein in 1839**. However in **1886 J. Soret** demonstrated that Ozone ($O_3$) was actually an allotrope of oxygen ($O_2$).

### Occurrence:

In nature ozone is formed from atmospheric oxygen by lightening flashes, however ozone is very unstable dissociates readily forming reactive oxygen atom.

$$O_{3(g)} \longrightarrow O_{2(g)} + \underset{\text{Atomic oxygen}}{O_{(g)}} \quad ; \qquad \Delta H = -107 KJ/mol.$$

Ozone exists in a layer at a height of about 20 kilometers above the earth where it is believed to protect the earth's surface form too much ultra violet radiation of the sun. Very small amount of ozone is produced around electrical machineries when they are in operations.

### Preparation:

Ozone can be prepared from oxygen by passing electric discharge through oxygen gas. It is necessary to use silent discharge because sparking would generate heat energy which decomposes ozone produced.

The apparatus used for converting oxygen into ozone is known as **ozonizer**.

$$\underset{\text{Oxygen}}{3O_{2(g)}} \xrightarrow{\text{electric discharge}} \underset{\text{Ozone}}{2O_{3(g)}}$$



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## PHYSICAL PROPERTIES:

(1) Ozone is a pale-blue gas at ordinary condition.

(2) Pure ozone can be obtained as blue liquid by cooling at −112°C.

(3) Ozone has characteristic smell which is sharp irritating like $Cl_2$ gas.

(4) Ozone is slightly soluble in water but dissolves in turpentine oil readily

(5) Ozone is very poisonous gas at concentration 100 parts per million (ppm). Exposure to 0.1 to 1 ppm in air produces headache, burning of eyes and irritation to the respiratory passages.

## CHEMICAL PROPERTIES:

Ozone is chemically more reactive than ordinary diatomic oxygen ($O_2$). It acts as powerful oxidizing agent because $O_3$ dissociates readily forming reactive oxygen atoms.

$$O_{3(g)} \longrightarrow O_{2(g)} + \underset{\text{Atomic oxygen}}{O_{(g)}} \quad ; \quad \Delta H = -107\,KJ/mol.$$

Ozone reacts with Lead sulphide (PbS), Sulphur dioxide ($SO_2$) and Potassium Iodide in acidic medium liberating oxygen ($O_2$) gas.

With PbS $\quad PbS_{(s)} + 4O_{3(g)} \longrightarrow \underset{\text{Lead sulphate}}{PbSO_{4(s)}} + 4O_{2(g)}$

With $SO_2$ $\quad SO_{2(g)} + O_{3(g)} \longrightarrow \underset{\text{Sulphur trioxide}}{SO_{3(g)}} + O_{2(g)}$

With KI $\quad 2KI_{(aq)} + O_{3(g)} + H_2SO_{4(aq)} \longrightarrow K_2SO_{4(aq)} + I_{2(aq)} + H_2O_{(l)} + O_{2(g)}$

## USES:

(1) Ozone is sometimes used in treatment of domestic water in place of chlorine. Like chlorine it kills bacteria and oxidizes organic compound present in water.

(2) It is used as bleaching agent because all oxidizing agents are also good bleaching agents.

(3) It is largely used in the preparation of pharmaceuticals, synthetic lubricants and other commercially useful organic compounds.

## IMPORTANCE:

Ozone is an important component of the upper atmosphere, where it serves to screen out the ultra-violet radiations of the sun. In this way ozone protects the earth from the harmful effects of high energy rays. For this reason, depletion of ozone layer is a major scientific concern, now-a-days. But in the lower atmosphere ozone is considered as air pollutant because of its oxidizing power, it causes damage to living systems.

# EXERCISE

(1) (a) **Fill in the blanks.**

(i) The yellow colour of nitric acid is due to dissolved ***nitrogen dioxide*** ***($NO_2$)*** gas.
(ii) When ***one*** mole of $N_2$ gas is mixed with ***three*** moles of $H_2$ gas, 2 moles of $NH_3$ gas is produced.
(iii) Nitric acid on the large scale is produced by ***Ostwald's*** method from ammonia.
(iv) Ammonia on the large scale is produced by ***Haber Bosch*** process.
Ozone is an ***allotropic*** form of ***oxygen*** with molecular formula $O_3$.
(vi) The powerful ultra violet radiation of the sun are screened by ***Ozone*** layer.
(vii) The process which takes place by the loss of electrons is called ***oxidation.***
(viii) In peroxides the oxidation state of oxygen is ***-1***.
(ix) The oxides that show acidic and basic characters are known as ***Amphoteric***.
(x) Nitrogen boils out from the liquid air at temperature $-$***196***°C.

(b) **Point out True or False in the following statements:**

(i) Oxygen is separated from the liquid air before nitrogen. **[False]**
(ii) Air contains about 21% $O_2$ gas by volume. **[True]**
(iii) Nitric acid acts as a powerful oxidizing agent. **[True]**
(iv) Hydrogen peroxide decomposes to liberate $O_2$ gas on exposure. **[True]**
(v) Ammonia gas is insoluble in water. **[False]**
(vi) Ozone exists at the height of about 20 Kilometers above the earth. **[True]**
(vii) The substance that accepts is used for the production of nitric acid. **[False]**
(viii) Haber's process is used for the production of nitric acid. **[False]**
(ix) Nitrogen in $HNO_3$ is in its highest oxidation state of +5. **[True]**
(x) Nitrogen belongs to VIA group of the periodic table. **[False]**

(c) **Pick up the correct answer form the following:**

(i) When ammonium chloride is heated with a base, the gas liberated is:
(a) *ammonia* (b) oxygen (c) nitrogen (d) nitric oxide (NO)

(ii) The catalyst used for the catalytic oxidation of $NH_3$ in Ostwald's method is:
(a) nickel (b) chromium
(c) *platinum* (d) vanadium penta oxide

(iii) The metal that liberates $H_2$ gas when treated with dil. $HNO_3$ is:
(a) copper (b) aluminium (c) zinc (d) *magnesium*

(iv) The boiling point of liquid oxygen is:
(a) −196°C (b) *−183°C* (c) −200°C (d) −187.5°C

(v) Select the redox reaction from following reactions:
(a) $Cl + Cl \longrightarrow Cl_{2(g)}$
(b) $CaCO_3 \longrightarrow CaO_{(g)} + CO_{2(g)}$
(c) $2FeCl_3 + H_2S \longrightarrow 2FeCl_2 + 2HCl + S$
(d) $N_2 \longrightarrow N^{\cdot} + N^{\cdot}$

(vi) The air we breathe in usually contains a higher proportion of:
(a) *nitrogen* (b) oxygen (c) carbon dioxide (d) water vapours

(vii) Which one of the following is the easy way to distinguish ozone from oxygen?
(a) by comparing their solubilities (b) by comparing their oxidizing properties
(c) by comparing allotropic forms (d) *by comparing their odours*

(viii) The most abundant element found in nature is:
(a) *oxygen* (b) silicon (c) nitrogen (d) hydrogen

(ix) Urea is produced by heating carbon dioxide ($CO_2$) with,
(a) nitric acid (b) *ammonia* (c) hydrogen (d) potassium nitrate

(x) Hydrogen peroxide is produced in the laboratory by heating sulphuric acid with:
(a) sodium peroxide (b) potassium peroxide
(c) *barium peroxide* (d) strontium peroxide

SESSION
2016-2017

# CLASS-IX

# CHEMISTRY

## Chapter # 14

## SULPHUR AND ITS COMPOUNDS

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# SULPHUR AND ITS COMPOUNDS 14

## INTRODUCTION:

Sulphur is the second member of VIA group of the periodic table and has symbol S, its atomic number is 16 while atomic mass is 32 a.m.u. Sulphur has been known for its medicinal and germicidal effect before 1000 B.C. but its chemical nature remained unknown until 1787 when Lavoisier recognized it as an element.

## ALLOTROPY:

The existence of an element in two or more different forms is called **Allotropy** and different forms are called **Allotropes or Allotropic forms.**

Chemical properties of allotropic forms are same but they have different physical properties due to different structures or arrangements of the atoms.

## Allotropic forms of Sulphur:

**(1) Crystalline Forms:**

(i) Rhombic Sulphur ($\alpha$ - Sulphur)

(ii) Monoclinic Sulphur ($\beta$ - Sulphur or prismatic)

**(2) Amorphous Form:**

(iii) Plastic Sulphur ($\gamma$- Sulphur)

## (i) Rhombic Sulphur ($\alpha$ - Sulphur):

It is the most stable **crystalline form** of sulphur at ordinary condition. Free Sulphur exits in nature as rhombic sulphur.

### Properties:

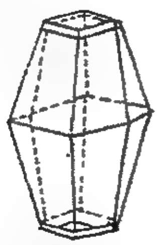
(1) It is pale-yellow crystals, giving lemon-yellow powder.
(2) Its melting point is 113°C.
(3) Its density is $2.08 g/cm^3$ at 20°C.
(4) It is stable at ordinary temperature.
(5) It is insoluble in water but soluble in carbon disulphide ($CS_2$), benzene ($C_6H_6$), disulphur dichloride or Sulphur mono chloride ($S_2Cl_2$), etc.

### Preparation:

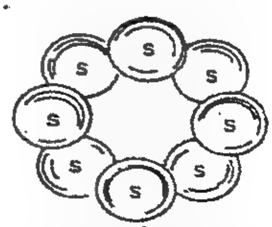
Rhombic Sulphur is prepared by slow evaporation of the solution of ordinary sulphur in carbon disulphide ($CS_2$). Now it is filtered first to remove insoluble impurities present in sulphur. The filterate on slow evaporation produces **octahedral** crystals of **rhombic** sulphur.

### Structure:

Rhombic Sulphur consists of eight *S* atoms. These **8 sulphur** atoms bonded to each other through single covalent bond. The shape of rhombic sulphur is given below:



Crystal of Rhombic Sulphur




Structure of $S_8$ molecules

## (ii) Monoclinic Sulphur (β or Prismatic Sulphur):

Monoclinic Sulphur is another **crystalline form** of sulphur.

### Properties:

(1) It is dark yellow transparent needle-like crystals. On standing the crystals become opaque, brittle and lemon yellow in colour.

(2) Its melting point is 119°C

(3) Its density is **1.96 g/cm³**.

(4) It is stable between **96 to 119°C** and hence it changes slowly to rhombic sulphur at ordinary temperature.

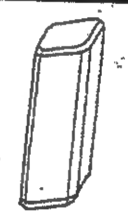
(5) It is insoluble in water but soluble in carbon disulphide ($CS_2$), benzene ($C_6H_6$), disulphur dichloride or sulphur mono chloride ($S_2Cl_2$). The transformation of monoclinic sulphur to rhombic sulphur is reversible and can be described as:

$$\text{Rhombic sulphur} \xrightleftharpoons{96^\circ C} \text{Monoclinic sulphur}$$

Below 96°C, the rhombic sulphur is stable and above 96°C, monoclinic sulphur is stable. Thus ***the temperature at which both crystalline forms coexist in equilibrium is called transition temperature.*** The transition temperature of sulphur is 96°C.

### Preparation:

Monoclinic sulphur is obtained by slow cooling molten sulphur until a crust is formed on the surface of the molten sulphur. Make two holes through the crust and pour out the remaining molten sulphur. On removing the crust the long needle shaped crystals of monoclinic sulphur are formed on the sides of the dish.



Crystal of monoclinic Sulphur

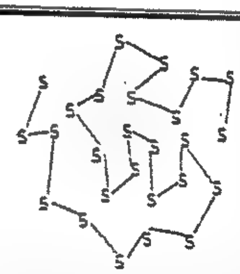
### Structure:

Monoclinic sulphur also consists of eight sulphur atoms. The only difference is the shapes of the crystals. The monoclinic sulphur, the $S_8$ molecule unite together to give long needle-shaped crystals.

## (iii) Plastic Sulphur (γ - Sulphur):

Plastic sulphur is a super cooled form of sulphur. It is the **amorphous form** of sulphur.

When ordinary sulphur is heated carefully upto its boiling point about **444.6°C** and then the molten sulphur is poured into very cold water thus a soft rubber like mass is obtained which looks like plastic material. It is unstable and reverts to rhombic sulphur on standing. It has zig-zag arrangements of sulphur atoms.



Plastic sulphur

## OCCURRENCE:

Sulphur is non-metal and makes up about 0.1% of the earth's crust. It is found in the Free State in Sicily, Mexico and USA. In USA large deposits of sulphur are found in Louisiana and Texas. It is also found in the Free State in Japan and New Zealand. In the combined state, it is largely found as sulphates of mangnesium, calcium and barium. In Pakistan some deposits of sulphur occur in Koh-i-Suleman and in Kalat.

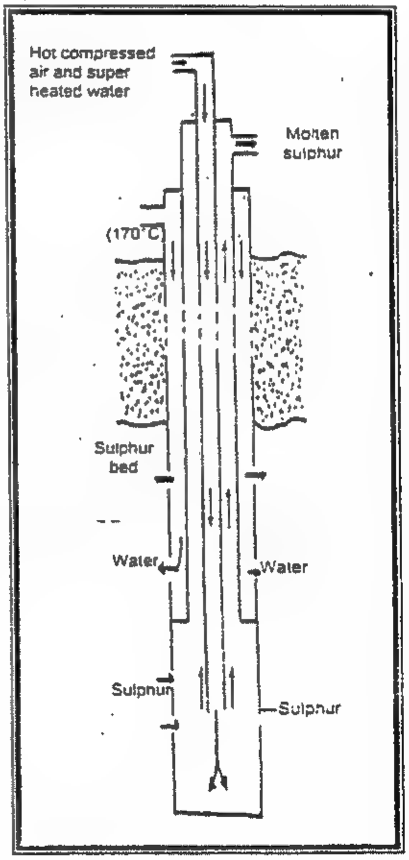
In addition to this, sulphur is an essential constituent of many organic substances of plant and animal origins such as proteins, eggs, onions, garlic and mustard, etc.

## EXTRACTION OF SULPHUR (FRASCH PROCESS):

## INTRODUCTION:

Free Sulphur deposits are found more than 200 meters below the surface of the earth. About 60-70% sulphur occurs deep below the earth's surface. For this reason sulphur can not be dug out directly by ordinary mining. An American engineer **Herman Frasch** developed a process for the extraction of sulphur. This process is known as Frasch process.

## CONSTRUCTION:




In this process, a hole about 30cm in diameter is drilled through the soil layers to the sulphur bed. Three concentric iron pipes are sunk into the bore or hole. The outer **most pipe (15 cm diameter)** is sunk up to the deposits and the next **inner pipe (10 cm diameter)** is held a little above the surface of the sulphur deposits. Finally 3rd **inner most pipe (5cm diameter)** inserted.

## PROCESS / WORKING:

### Outer Most Pipe (15 cm diameter):

Super heated water at about **170°C and 100 atmospheric** pressure is forced through this pipe to the sulphur bed to melt sulphur (**m.p = 113°C**).

### Inner Pipe (10 cm diameter):

This pipe prevents solidifying the molten sulphur by high temperature which is maintained by the super-heated water.

### Inner Most Pipe (5 cm diameter):

Hot and compressed air at a pressure of 15 atm is flown down to force the **molten sulphur** up to the surface through this pipe.

The molten sulphur is continuously pumped out from the same process and store in the large wooden tanks. The sulphur obtained is about 99.5% pure.

# PROPERTIES OF SULPHUR:

## Physical properties:

(1) Sulphur is a pale yellow solid.

(2) It is a non-metal. It is bad conductor of heat and electricity.

(3) It is insoluble in water but soluble in carbon disulphide ($CS_2$), benzene ($C_6H_6$), disulphur dichloride or Sulphur mono chloride ($S_2Cl_2$).

(4) It melts at a temperature between 113°C to 119°C into an amber coloured ... The colour darkens as the temperature increases. Its boiling point is about 444°C.

## Chemical properties:

### (1) Reactions with Metals:

Sulphur combines with many metals directly to form their respective sulphides. Reactive metals like sodium, potassium may even react with sulphur spontaneously without much more heating, when both are in finely divided form.

(i) $2Cu_{(s)} + S_{(s)} \xrightarrow{heat} Cu_2S_{(s)}$ (Cuprous sulphide)

(ii) $Fe_{(s)} + S_{(s)} \xrightarrow{heat} FeS_{(s)}$ (Ferrous sulphide)

(iii) $2Na_{(s)} + S_{(s)} \xrightarrow{heat} Na_2S_{(s)}$ (Sodium sulphide)

### (2) Reaction with Non-Metals:

Many non-metals react with sulphur at different conditions:

### (a) With Oxygen:

Sulphur burns in oxygen (air) with a bright blue flame to form sulphur dioxide.

$$S_{(s)} + O_{2(g)} \xrightarrow{Ignition} SO_{2(g)}$$

### (b) With Hydrogen:

At 600°C, sulphur combines with hydrogen slowly to form hydrogen sulphides ($H_2S$) gas. The reaction is more rapid if hydrogen is bubbled through molten sulphur.

$$H_{2(g)} + S_{(s)} \xrightarrow{600°C} H_2S_{(g)}$$

### (c) With Carbon:

Sulphur combines with coke in electric furnace to form colourless liquid, carbon disulphide ($CS_2$). This vapourizes readily forming poisonous and highly inflammable fumes. $CS_2$ is used as solvent for waxes, gums and sulphur.

$$C_{(s)} + 2S_{(s)} \xrightarrow{Electric\ furnace} CS_{2(l)}$$

### (d) With Chlorine:

Sulphur combines with chlorine on heating to high temperature, forming disulphur dichloride or sulphur mono chloride ($S_2Cl_2$).

$$2S_{(s)} + Cl_{2(g)} \xrightarrow{high\ temperature} S_2Cl_{2(l)}$$

### (e) With Fluorine:

Sulphur combines with fluorine on heating to form sulphur hexa fluoride ($SF_6$)

$$S_{(s)} + 3F_{2(g)} \xrightarrow{Hot} SF_{6(l)}$$

## 3. Reaction with Acids:

Sulphur is readily oxidized when warmed with concentrated Sulphuric acid to produce $SO_2$ gas and also with concentrated nitric acid to produce $NO_2$ gas.

(i) $S_{(s)} + 2H_2SO_{4(conc)} \xrightarrow{Hot} 3SO_{2(g)} + 2H_2O_{(l)}$

(ii) $S_{(s)} + 6HNO_{3(conc)} \longrightarrow H_2SO_{4(aq)} + 6NO_{2(g)} + 2H_2O_{(l)}$

## Uses of Sulphur:

(1) Sulphur is used in the manufacture of Sulphuric acid, sulphur dioxide and carbon disulphide.

(2) It is used for the manufacture of calcium and magnesium hydrogen sulphide.

(3) It is used for bleaching wood-pulp.

(4) Sulphur is used in vulcanizing rubber.

(5) It is used for disinfecting houses. It also helps to kill the fungi and insects.

## SULPHURIC ACID ($H_2SO_4$):

Sulphuric acid is one of the most important chemical compounds. It is also called **king of chemicals** or **oil of vitriol**. It is commonly used in the laboratory and in industries in many processes.

## Industrial Preparation of Sulphuric Acid:

On the large scale Sulphuric acid is manufactured by the Contact process.

### The Contact Process:

This method was developed in Germany in the early 19th century but came into operation from **1912**. The details are given below:

**Step# 1:**

$SO_2$ is produced mainly by burning sulphur in dry air or iron pyrite in pyrite burners. The $SO_2$ which is produced is **impure**.

$$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$$

$$4FeS_{2(s)} + 11O_{2(g)} \longrightarrow 2Fe_2O_{3(s)} + 8SO_{2(g)}$$

**Step# 2:**

**Impure** $SO_2$ and **air** is passed through different chambers so that these gases become purified. The solid particles settle down in the dust chamber. Now $SO_2$ is passed through the washing chamber. Here steam is injected from the top of the chamber. Solid particles are settled down. The moist mixture of $SO_2$ and air is passed through the drying towers in which concentrated $H_2SO_4$ is sprayed from the top so that water vapours are removed from the mixture.

**Step# 3:**

This washed dried and purified mixture of $SO_2$ and air is passed through contact tower i.e. catalytic chamber. In this tower $SO_2$ is oxidized to $SO_3$ in the presence of catalyst **vanadium penta oxide** ($V_2O_5$). The reaction occurs as:

$$2SO_{2(g)} + O_{2(g)} \xrightarrow{V_2O_5} 2SO_{3(g)};\Delta H = -197KJ/mol.$$

Since the reaction is reversible and exothermic so some optimum conditions are required i... ...atmosphere.

**Step# 4:**

The **sulphur trioxide** ($SO_3$) is absorbed in concentrated Sulphuric acid which produces a very thick liquid called **oleum** (Pyro-Sulphuric acid), in the absorption tower. ($SO_3$ is less soluble in water).

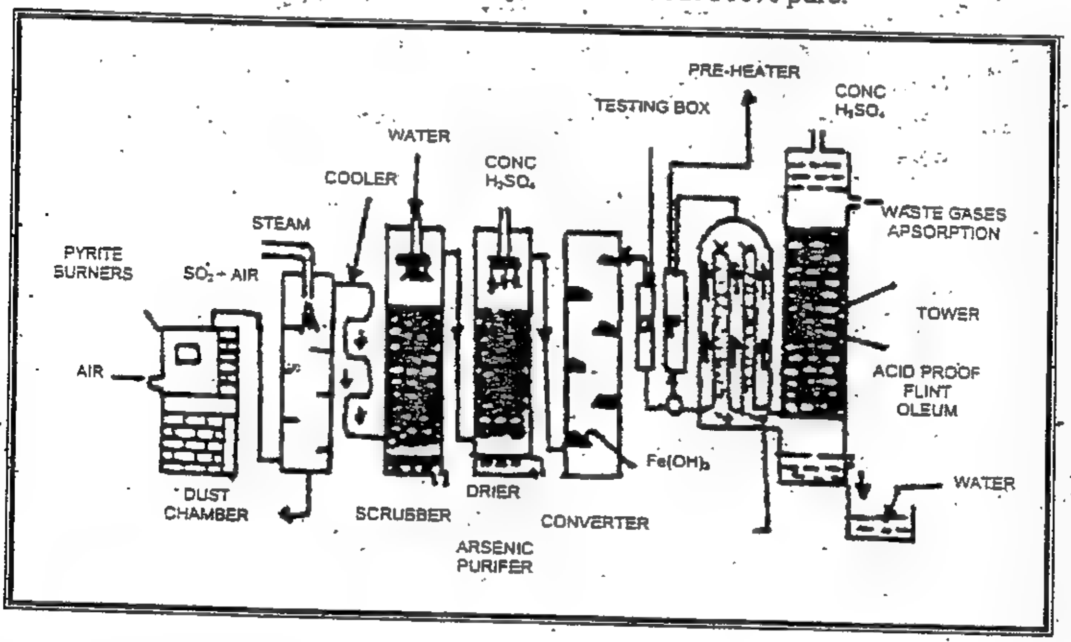
$$SO_{3(g)} + H_2SO_{4(conc)} \longrightarrow H_2S_2O_{7(l)}$$

**Step# 5:**

Oleum is then diluted with appropriate amount of water to get Sulphuric acid of desired concentration.

$$H_2S_2O_{7(aq)} + H_2O_{(l)} \longrightarrow 2H_2SO_{4(aq)}$$

Sulphuric acid obtain by the contact process is about 100% pure.




## Physical Properties:

(1) Pure Sulphuric acid is colourless, odorless, viscous oil like liquid. often known as **oil of vitriol.**

(2) Its melting point is **10.5°C** while its boiling point is **338°C.**

(3) Concentrated $H_2SO_4$ (98.3%) has specific gravity about 1.84. while dilute 65% Sulphuric acid has specific gravity about 1.55.

(4) It is corrosive and is hygroscopic as it absorbs water vapours from the surroundings and becomes dilute. It is therefore used as drying agent.

## Chemical Properties:

Sulphuric acid behaves in three different ways:

(1) as an acid, (2) as an oxidizing agent (3) as drying or dehydrating agent

## (1) As an Acid:

Sulphuric acid is a strong dibasic acid and ionizes in water in two stages.

(a) $H_2SO_{4(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^-_{(aq)} + HSO_4$

Hydronium ion Hydrogen sulphate ion

(b) $HSO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + SO_4^{2-}$

Sulphate ion

Sulphuric acid reacts with alkalis (bases) to give two types of salts: hydrogen sulphate and sulphate.

(1) $NaOH_{(aq)} + H_2SO_{4(aq)} \longrightarrow NaHSO_{4(aq)} + H_2O_{(l)}$

(Sodium hydrogen sulphate)

(2) $NaHSO_{4(aq)} + NaOH_{(aq)} \longrightarrow Na_2SO_{4(aq)} + H_2O_{(l)}$

(Sodium sulphate)

Sulphuric acids also react with metal oxides (basic oxides) like MgO to from salt and water.

$$MgO_{(s)} + H_2SO_{4(aq)} \longrightarrow MgSO_{4(aq)} + H_2O_{(l)}$$

## (2) As an Oxidizing Agent:

Sulphuric acid acts as oxidizing agent. The oxidizing properties of $H_2SO_4$ depend upon (i) concentration of the acid (ii) nature of the metal or reducing agent (iii) temperature.

## Reaction with Metals:

Less electropositive metal like Zn, Fe, Al react with dilute Sulphuric to liberate $H_2$ gas and forming their **Sulphates.**

(i) $Fe_{(s)} + H_2SO_{4(aq)} \xrightarrow{\text{dilute}} FeSO_{4(aq)} + H_{2(g)}$

(ii) $2Al_{(s)} + 3H_2SO_{4(aq)} \xrightarrow{\text{dilute}} Al_2(SO_4)_{3(aq)} + 3H_{2(g)}$

Hot concentrated Sulphur acid oxidizes some metal to their **sulphates** liberating $SO_2$ gas.

$Cu_{(s)} + 2H_2SO_{4(aq)} \xrightarrow[\text{Hot}]{\text{conc.}} CuSO_{4(aq)} + SO_{2(g)} + 2H_2O_{(l)}$

$Pb_{(s)} + 2H_2SO_{4(aq)} \xrightarrow[\text{Hot}]{\text{conc}} PbSO_{4(g)} + SO_{2(g)}\ 2H_2O_{(l)}$

$2Al_{(s)} + 6H_2SO_{4(aq)} \xrightarrow[\text{Hot}]{\text{Conc.}} Al_2(SO_4)_{3(aq)} + 3SO_{2(g)} + 6H_2O_{(l)}$

Reactive metal with concentrated $H_2SO_4$ form different products. Zinc reacts with 90% concentrated $H_2SO_4$ to liberate $H_2S$ gas.

$4Zn_{(s)} + 5H_2SO_{4(aq)} \xrightarrow{90\%} 4ZnSO_{4(s)} + H_2S_{(g)} - 4H_2O_{(l)}$

## Reaction with Non-Metals:

Hot and concentrated Sulphuric acid oxidizes some non-metals like C, S and P into their oxides.

$$C_{(s)} + 2H_2SO_{4(conc)} \xrightarrow[Hot]{} CO_{2(g)} + 2SO_{2(g)} + 2H_2O_{(l)}$$

$$2P_{(s)} + 3H_2SO_{4(conc)} \xrightarrow[Hot]{} 2H_3PO_{4(aq)} + 3SO_{2(g)}$$

## Reaction with Compounds:

Concentrated Sulphuric acid oxidizes hydrogen sulphide ($H_2S$) to sulphur and HI is oxidized to vapours of $I_2$.

$$H_2S_{(aq)} + H_2SO_{4(conc)} \longrightarrow S_{(s)} + SO_{2(g)} + 2H_2O_{(l)}$$

$$2HI_{(aq)} + H_2SO_{4(conc)} \longrightarrow I_{2(g)} + SO_{2(g)} + 2H_2O_{(l)}$$

## (3) As Drying or Dehydrating Agent:

The hot and concentrated $H_2SO_4$ acts as powerful drying or dehydrating agent. It removes water from the compounds like sugar, ethanol, formic acid, oxalic acid, etc. The process of removing water from a compound is called **dehydration** and the compound which can remove water is called **dehydrating agent**.

$$\underset{\text{Sugar}}{C_{12}H_{22}O_{11(s)}} \xrightarrow[hot]{conc\,H_2SO_4} \underset{\text{Charred Mass}}{12C_{(s)}} + 11H_2O_{(l)}$$

$$\underset{\text{Ethanol}}{CH_3-CH_2-OH_{(l)}} \xrightarrow[170°C]{conc\,H_2SO_4} \underset{\text{Ethene}}{CH_2=CH_{2(g)}} + H_2O_{(l)}$$

$$\underset{\text{Formic acid}}{HCOOH_{(l)}} \xrightarrow{conc.\,H_2SO_4} CO_{(g)} + H_2O_{(l)}$$

$$\underset{\text{Oxalic acid}}{\begin{matrix} COOH \\ | \\ COOH_{(s)} \end{matrix}} \xrightarrow{conc.\,H_2SO_4} CO_{(g)} + CO_{2(g)} + H_2O_{(l)}$$

$$\underset{\text{Blue (hydrate)}}{CuSO_4.5H_2O_{(s)}} \xrightarrow{conc.\,H_2SO_4} \underset{\text{White (anhydrous)}}{CuSO_{4(s)}} + 5H_2O_{(g)}$$

## Uses of Sulphuric Acid:

Sulphuric acid is the most important chemical (compound) and is extensively used in industries. The progress and the prosperity of any nation can be estimated in terms of the amounts of sulphuric acid consumed annually. It is therefore. barometer of industrial and economical progress of a country.

## Important uses of $H_2SO_4$:

(1) It is used for refining of petroleum.

(2) It is also used as an oxidizing agent.

(3) It is used as the dehydrating (drying) agent.

(4) It is used in the manufacture of paints and pigments.

(5) It is used in the motor car batteries and lead accumulators.

(6) It is used in the pickling (cleaning) the metals for electrolysis.

(7) It is used in the manufacture of Rayon, paper, plastics and detergents.

(8) It is used in the making cellulose film and all kinds of man-made fabrics.

(9) It is used in the manufacture of fertilizers; about one quarter of sulphric acid produced in the world is consumed for the production of two main fertilizer; dihydrogen calcium phosphate (super phosphate) $Ca(H_2PO_4)_2$ and ammonium sulphate $(NH_4)_2SO_4$.



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# EXERCISE

**(1) Fill in the blanks.**

(i) Rhombic sulphur is the most ***stable*** form of sulphur.

(ii) Monoclinic sulphur has needle like

(iii) $CS_2$ is a good solvent for ***sulphur***.

(iv) The melting point of monoclinic sulphur is ***119°C***.

(v) Pure sulphuric acid on large scale is manufactured by the ***contact*** process.

(vi) Phosphorous with hot concentrated $H_2SO_4$ oxidizes to ***phosphoric acid***.

(vii) Ethene gas evolves when ***Ethanol*** is dehydrated by hot concentrated $H_2SO_4$.

**(2) Tick true or false for the following statements:**

(i) Plastic sulphur is hard. [F]

(ii) Monoclinic sulphur is stable above 96°C. [T]

(iii) Sulphur is extracted by the direct mining from the earth's deposits. [F]

(iv) Concentrated sulphuric acid has greater affinity for water. [T]

(v) Concentrated sulphuric acid reduces to $SO_2$ when acts as oxidizing agent. [T]

(vi) It the manufacture of sulphuric acid, $SO_3$ is directly dissolved in water to produce oleum. [F]

(vii) Concentrated $H_2SO_4$ removes water from sugar to leave charred mass. [T]

**(3) Pick up the correct answer:**

(i) The formula of iron pyrite for getting $SO_2$ from pyrite burner is:

(a) FeS (b) $Fe_2S_3$ **(c) $FeS_2$** (d) $Fe_2S_2$

(ii) The non crystalline from of sulphur is

**(a) Plastic sulphur** (b) Rhombic sulphur

(c) Monoclinic sulphur (d) Ordinary sulphur

(iii) The specific gravity of 98.3% concentrated $H_2SO_4$ is:

(a) 1.5 (b) **1.84** (c) 1.80 (d) 1.91

(iv) The density of rhombic sulphur is:

(a) 1.96 (b) 1.92 (c) 2.4 (d) **2.08**

(v) Rhombic sulphur has structure of shape:

(a) Square planar (b) **Octahedral**

(c) Tetrahedral (d) Prismatic

(vi) The Optimum condition of temperature for the maximum yield of $SO_3$ in Contact process is:

(a) 350°C (b) **450°C** (c) 1700°C (d) 900°C

(vii) Sulphur burns in oxygen with blue flame to produce:

(a) $SO_3$ (b) $H_2S$ (c) $S_2Cl_2$ (d) $\mathbf{SO_2}$

(4) (a) What is allotropy? Describe different allotropic forms of sulphur.

**Answer on page # 3**

(b) What is plastic sulphur? Why is it elastic?

**Answer on page # 4 Plastic sulphur is elastic because it is soft and rubber like when obtained.**

(c) What is the action of sulphur on heating with?

(i) Cu (ii) C (iii) $Cl_2$ (iv) Na

**Answer on page # 6 and 7**

(d) Given four uses of sulphur.

**Answer on page # 7**

(5) (a) Describe and explain, how sulphur is extracted from underground deposits by Frasch process.

**Answer on page # 5**

(b) Complete the following reactions with balanced equations.

(i) $FeS_{2(s)} + O_{2(g)} \longrightarrow$ Page # 7

(ii) $Fe_{(s)} + S_{(s)} \longrightarrow$ Page # 6

(iii) [illegible]

(iv) $S_{(s)} + HNO_{3(conc)} \xrightarrow{Hot}$ Page # 7

(v) $SO_{3(g)} + H_2SO_{4(conc)} \xrightarrow{Hot}$ Page # 8

(6) (a) Discuss various stage in the manufacture of sulphuric acid by the Contact process, given equation of the reactions involved.

What is the catalyst used in the process?

**Answer on page # 7 and 8**

(b) Explain why $SO_2$ is purified before it is passed into the Contact tower for its oxidation to $SO_3$.

**Answer on page # 7 in Step # 2**

(c) Show that sulphuric acid acts as:

(i) Oxidizing agent (ii) Dehydration.

**Answer on page # 9 and 10**

(d) With the help of equation, describe the action of concentrated sulphuric acid on:

(i) *Al* metal (ii) C

(iii) $C_{12}H_{22}O_{11}$ (iv) Blue $CuSO_4.5H_2O$.

(e) Give the importance of sulphuric acid and its uses.

**Answer on page# 11**

SESSION
2016-2017

PRACTICAL CENTRE KARACHI

# CLASS-IX

# CHEMISTRY

## Chapter # 15

## HALOGENS

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# HALOGENS

**15**

## INTRODUCTION:

Halogens are the elements of VII-A group of the periodic table. This group consists of Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I) and Astatine (At) ...ogens. Derived name from Greek word meaning Salt producer (**Halo means Salt, Gene means Producing**), because these elements combine with metals to form salts (ionic compounds).

## REACTIVITY:

Halogens are the most reactive group of non-metals. These are strong oxidizing agents. Oxidizing power decreases from $F_2$ to $I_2$. Halogens exist as diatomic molecules $F_2$, $Cl_2$, $Br_2$ and $I_2$.

## STATES:

Fluorine and chlorine are gases, $F_2$ is pale yellow gas and $Cl_2$ is greenish yellow gas or pale green. Bromine ($Br_2$) is a volatile reddish brown liquid. Iodine ($I_2$) is shiny black solid that sublimes readily giving violet vapors.

| Element | Fluorine($F_2$) | Chlorine($Cl_2$) | Bromine($Br_2$) | Iodine ($I_2$) |
|---|---|---|---|---|
| Atomic number | 9 | 17 | 35 | 53 |
| Electronic configuration | 2,7 | 2,8,7 | 2,8,18,7 | 2,8,18,18,7 |
| Colour | Pale yellow | Pale green | Reddish brown | Black |
| State at 20°C | Gas | Gas | Liquid | Solid |
| Electro negativity | 4.0 | 3.0 | 2.8 | 2.5 |
| Melting point (°C) | -220 | -101 | -7 | 113 |
| Boiling point (°C) | -188 | -35 | 59 | 183 |
| Atomic size (A°) | 0.71 | 0.99 | 1.14 | 1.33 |
| Ionic size (A°) | 1.33 | 1.81 | 1.96 | 2.20 |
| Bond energy (KJ / mol) | 155 | 242 | 193 | 151 |
| Electron affinity (KJ / mol) | -328 | -349 | -325 | -295 |

## OCCURRENCE OR SOURCES:

The halogens are so reactive so they can not exist in the Free State in nature.

Fluorine occurs in the minerals, the compounds of fluorine are:

**Fluorspar ($CaF_2$), Cryolite ($Na_3AlF_6$) and Fluorapatite $3Ca_3(PO_4)_2\,CaF_2$**

Chlorine is abundant in oceans and salt deposits as **Sodium Chloride** i.e, rock salt (NaCl). Each kilogram of sea water contains about 30g of NaCl (3%). The large salt deposits in Pakistan at Khewra near Jhelum.

Bromine is less abundant and is found as bromide (Br) of Na and K in sea water. Sea water contains very small concentration of bromide (70 ppm by mass), however this amount is still possible for its extraction.

Iodine is even less abundant than bromine. Sea water contains traces of iodide (0.05 ppm by mass). Iodine is also present as sodium iodide (NaI) in certain oil-wells and also as sodium iodate ($NaIO_3$), found along with Chile salt Peter ($NaNO_3$).

Astatine does not occur naturally. It is very unstable radioactive element.

## IMPORTANCE OF HALOGENS IN DAILY LIFE:

Except chlorine, the halogens have limited uses; however their compounds ... agriculture, medicines and homes.

## USES (APPLICATION / IMPORTANCE) OF FLUORINE:

(i) Fluorine is used to make wide range of fluoro chloro carbon compounds which are used as refrigerants, aerosol propellants, anesthetics and fire-extinguisher fluids.

(ii) **Teflon** (poly tetra fluoroethene) or **PTFE** is used as electrical insulator (wire coverings). It is also used to prepare non-stick utensils and pans.

(iii) Stannous fluoride ($SnF_2$) is used in tooth pastes for preventing tooth decay; Hydrofluoric acid (HF) torch produces temperature upto 4000 °C and is used in welding purposes.

(iv) Small quantity of fluorine is used in rocket propulsion.

## USES (APPLICATION / IMPORTANCE) OF CHLORINE:

Following are the some common uses of chlorine:

(i) Chlorine is used extensively in the production of dyes, drugs, explosives, etc.

(ii) It is used for preparation of Poly Vinyl Chloride $(CH_2{=}CHCl)_n$ a common plastic.

(iii) It is used in the preparation of D.D.T (dichloro diphenyl trichloro ethane) and hexachloro cyclohexane which are effective pesticides.

(iv) It is used in the preparation of bleaching powder which is used in bleaching the cotton, linen clothes.

(v) It is used for sterilizing drinking water and disinfecting drainages and sewers to kill pathogenic organisms.

(vi) It is used in the production of some poisonous gases of warfare such as **Phosgene.** $COCl_2$ and **Mustard gas**, $(C_2H_4Cl)_2S$.

(vii) It is used in the manufacture of chloroform ($CHCl_3$), carbon tetra chloride ($CCl_4$) which are organic non polar solvents and in the production of sulphur monochloride ($S_2Cl_2$), a vulcanizing agent.

Inspite of its importance in the daily life, chlorine is described as ***Satanic element***. This is just because of its compounds which are considered to be dangerous.

## USES (APPLICATION / IMPORTANCE) OF BROMINE:

(i) Bromine compounds are used in Pharmaceuticals.

(ii) Bromine compounds are used in dyes, fumigants and pesticides.

(iii) Bromine compounds are also used in fire-extinguishers and fire retardants.

(iv) Silver bromide ($AgBr$) is used in photographic films, being light sensitive.

## USES (APPLICATION / IMPORTANCE) OF IODINE:

(i) Iodine and its [illegible]

(ii) Iodine is used in medicine and in photographic films emulsion ($AgI$).

(iii) Iodide ion is used in thyroid glands, a product that is mainly $NaCl$ but includes a small quantity of $NaI$ or $KI$.

(iv) Mixture of Iodine in ethyl alcohol (***Tincture of Iodine***) is used as mild antiseptic for cuts and scratches.

## CHLORINE:

Chlorine is the second member of halogen family i.e. VIIA group of the periodic table. Chlorine is the most abundant member of VIIA group.

Chlorine was discovered by **Scheele** a Swedish chemist by the action of hydrochloric acid on manganese dioxide ($MnO_2$). The name chlorine to the gas was suggested in **1810** by **Sir Humphry Davy** from Greek word *Chloros* means pale green, because the colour of the gas is pale green. We feel smell of chlorine in drinking water, in swimming pools, it has slightly irritating and chocking smell.

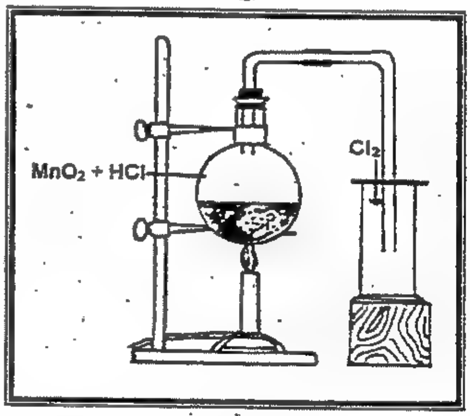
## PREPARATION OF CHLORINE:

### (1) IN THE LABORATORY:

When concentrated hydrochloric acid ($HCl$) is heated with oxidizing agent (like $MnO_2$, $KMnO_4$ or $KClO_3$) then chlorine gas ($Cl_2$) is produced.

(i) $MnO_{2(s)} + 4HCl_{(conc)} \xrightarrow{Heat} MnCl_{2(aq)} + 2H_2O_{(l)} + Cl_{2(g)}$

In this method, a mixture of Manganese dioxide ($MnO_2$) and concentrated Hydrochloric acid ($HCl$) is taken in round bottom flask, as shown in the figure fitted with a cork, containing a delivery tube. On gentle heating greenish yellow chlorine gas comes out which is collected by the **upward displacement of air** in a gas jar through the delivery tube.




It is a poisonous gas so efficient ventilation in the laboratory is necessary.

(ii) $2KMnO_{4(s)} + 16HCl_{(conc)} \xrightarrow{Heat} 2KCl_{(aq)} + 2MnCl_{2(aq)} + 8H_2O_{(l)} + 5Cl_{2(g)}$

In this method, a mixture of Potassium permanganate ($KMnO_4$) and concentrated Hydrochloric acid ($HCl$) is taken in the flask. On constant heating greenish yellow chlorine gas comes out from the flask.

(iii) $2NaCl_{(s)} + 2H_2SO_{4(conc)} + MnO_{2(s)} \xrightarrow{Heat} Na_2SO_{4(aq)} + 2H_2O_{(l)} + Cl_{2(g)}$

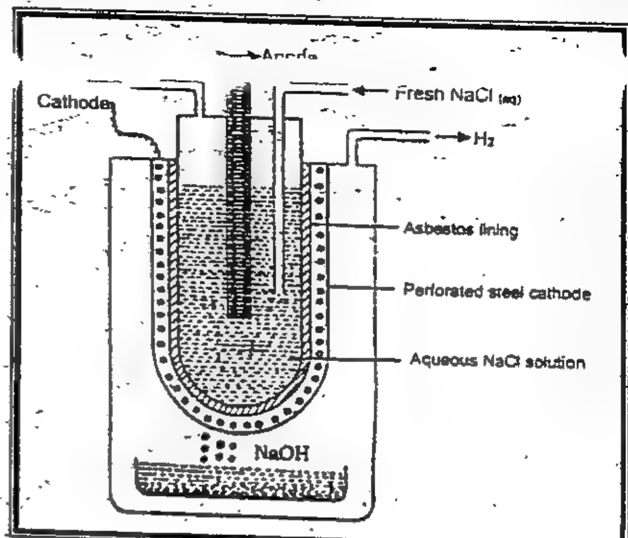
In this method, a mixture of Sodium Chloride ($NaCl$), Concentrated Sulphuric acid ($H_2SO_4$) and Manganese dioxide ($MnO_2$) is heated then greenish yellow chlorine gas is liberated.

## (2) IN THE INDUSTRY (COMMERCIAL / LARGE SCALE):

Chlorine gas on large scale is prepared by the electrolysis of sodium chloride solution. For this purpose two different methods are used which are described below:

### (i) FROM NELSON'S CELL:

**Construction:**




U-shaped perforated **steel vessel**, which acts as **cathode**. The **graphite anode** is dipped in the salt solution in the middle of U-shaped vessel. The U-shaped tank is separated from anode by **asbestos lining** or diaphragm. Through the asbestos lining, the salt solution slowly flows. The U-tube is known as **anode compartment** and this U-tube is fixed in an outer compartment, known as **cathode compartment**.

**Working:**

On passing electric current through the salt (NaCl) solution, **Chlorine** gas ($Cl_2$) is produced at **anode**, which rises into the dome at the top of the anode and then collected in the separate containers. **Sodium** (Na) metal is produced at **cathode** and then reacts with water of the solution flowing through the asbestos lining to release hydrogen (**$H_2$**) gas with the formation of sodium hydroxide (**NaOH**) solution which is collected at the **bottom** of the cathode compartment.

Following reactions take place in the cell:

**Ionization reaction:**

$$2NaCl_{(s)} \xrightleftharpoons{H_2O} 2Na^+_{(aq)} + 2Cl^-_{(aq)}$$

**Reaction at anode:**

$$2Cl^-_{(aq)} \longrightarrow Cl_{2(g)} + 2e^-$$

**Reaction at cathode:**

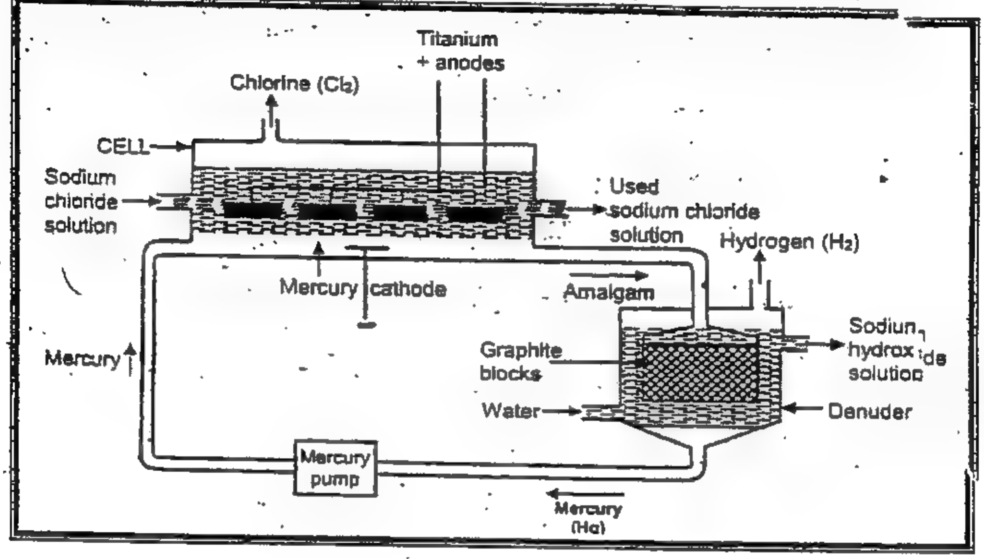
$$2Na^+_{(aq)} + 2e^- \longrightarrow 2Na_{(s)}$$

$$2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$$

## (ii) FROM CASTNER-KELLNER'S CELL:

This cell is consisted of two compartments as shown in the figure. The upper compartment has **mercury** at the **bottom** of the cell which acts as **cathode**. **Brine** (Saturated solution of $NaCl$) is poured in this cell. **Anodes are titanium** plates dipped in the brine. There is also a lower compartment known as **Soda cell** or **Denuder** which is packed with **graphite blocks**.

On [illegible] collected outside the anodes. $Na^+$ ions are discharged at **cathode** and form sodium amalgam (a mixture of Sodium metal with Mercury).




### Ionization reaction:

$$2NaCl_{(s)} \xrightleftharpoons{H_2O} 2Na^+_{(aq)} + 2Cl^-_{(aq)}$$

### Reaction at anode:

$$2Cl^-_{(aq)} \longrightarrow Cl_{2(g)} + 2e^-$$

### Reaction at cathode:

$$2Na^+_{(aq)} + 2e^- \longrightarrow 2Na_{(s)}$$

$$2Na_{(s)} + 2Hg_{(l)} \longrightarrow 2Na/Hg \quad \textbf{(sodium amalgam)}$$

Sodium amalgam is then sent to soda cell where it reacts with water to produce NaOH solution and $H_2$ gas while free mercury is recycled and then sent back to the upper cell.

$$2Na/Hg_{(l)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(g)} + 2H_{2(g)} + 2Hg_{(l)}$$

## PHYSICAL PROPERTIES:

1. Chlorine is a greenish yellow gas with sharp pungent (irritating) smell.
2. It is 2.5 times heavier than air.
3. Its density is $3.214 g/dm^3$ at S.T.P.
4. It boils at -35°C and melts at -101°C.
5. It is fairly soluble in water and its solution in water is called **Chlorine water**.

## CHEMICAL PROPERTIES (REACTIONS):

Chlorine is a non-metallic element. It is chemically very reactive and combines with majority of the elements to form binary compounds, known as **Chlorides.**

### (i) Reaction with Metals:

Chlorine reacts with all metals on heating to form their chlorides.

$$2Na_{(s)} + Cl_{2(g)} \xrightarrow{heat} 2NaCl_{(s)} \quad \textbf{(Sodium chloride)}$$

$$Zn_{(s)} + Cl_{2(g)} \longrightarrow ZnCl_{2(s)} \quad \textbf{(Zinc chloride)}$$

$$2Fe_{(s)} + 3Cl_{2(g)} \xrightarrow{heat} 2FeCl_{3(s)} \quad \textbf{(Ferric chloride)}$$

### (ii) Reaction with Non- Metals:

Chlorine reacts with non – metals on heating to form their chlorides.

$$2P_{(s)} + 3Cl_{2(g)} \xrightarrow{heat} 2PCl_{3(l)} \quad \textbf{(Phosphorous trichloride)}$$

$$2P_{(s)} + 5Cl_{2(g)} \xrightarrow{heat} 2PCl_{5(s)} \quad \textbf{(Phosphorous pentachloride)}$$

$$2S_{(s)} + Cl_{2(g)} \xrightarrow{heat} S_2Cl_{2(l)} \quad \textbf{(Sulphur monochloride)}$$

### (iii) Reaction with Hydrogen:

Chlorine reacts with hydrogen in presence of sunlight to form hydrogen chloride.

$$H_{2(g)} + Cl_{2(g)} \xrightarrow{Sunlight} 2\,HCl_{(g)}$$

### (iv) Reaction with Sodium Hydroxide:

When $Cl_2$ gas is passed through **cold solution** of caustic soda (NaOH) then Sodium **hypochlorite** and sodium chloride are formed.

$$Cl_{2(g)} + 2NaOH_{(aq)} \xrightarrow{cold} NaCl_{(aq)} + NaClO_{(aq)} + H_2O_{(l)}$$

When $Cl_2$ gas is passed through **hot solution** of caustic soda (NaOH) then Sodium **chlorate** and sodium chloride are formed.

$$3Cl_{2(g)} + 6NaOH_{(aq)} \xrightarrow{hot} 5NaCl_{(aq)} + NaClO_{3(aq)} + 3H_2O_{(l)}$$

### (v) Reaction with Ammonia:

Chlorine reacts with ammonia gas ($NH_3$) as a result Nitrogen gas and Hydrogen chloride are formed and then Hydrogen chloride reacts with excess of $NH_3$ to produce white fumes of Ammonium chloride ($NH_4Cl$).

(i) $2NH_{3(g)} + 3Cl_{2(g)} \longrightarrow N_{2(g)} + 6HCl_{(g)}$

(ii) $6NH_{3(g)} + 6HCl_{(g)} \longrightarrow 6NH_4Cl_{(s)}$ **(white fumes)**

### (vi) Reaction with Calcium Hydroxide (Lime Water):

Chlorine reacts with lime water as a result bleaching powder ($CaOCl_2$) is formed.

$$\underset{\textbf{(Lime water)}}{Ca(OH)_{2(aq)}} + Cl_{2(g)} \longrightarrow \underset{\textbf{Calcium oxychloride (Bleaching powder)}}{Ca(OCl)Cl_{(s)}} + 2H_2O$$

### (vii) Bleaching Action (AUTO OXIDATION-REDUCTION):

Chlorine in the presence of water acts as powerful oxidizing as well as bleaching agent. Chlorine gas ($Cl_2$) reacts with water and under goes **auto oxidation-reduction** due to the formation of hypochlorous acid (HOCl) and hydrochloric acid (HCl) with the liberation of nascent oxygen.

$$Cl_{2(g)} + H_2O_{(l)} \longrightarrow HCl_{(aq)} + HOCl_{(aq)}$$

$$HClO_{(aq)} \longrightarrow HCl_{(aq)} + [O] \text{ Nascent oxygen}$$

Chlorine oxidizes green coloured Ferrous chloride ($FeCl_2$) to reddish brown coloured Ferric chloride ($FeCl_3$).

$$\underset{\textbf{(Green)}}{2FeCl_{2(aq)}} + Cl_{2(g)} \longrightarrow \underset{\textbf{(Reddish brown)}}{2FeCl_{3(aq)}}$$

### (viii) Substitution Reaction:

Chlorine replaces one or more atoms or ions from other compounds such reactions are called substitution reactions.

$$2KBr_{(aq)} + Cl_{2(g)} \longrightarrow 2KCl_{(aq)} + Br_{2(l)}$$

$$H_2S_{(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)} + S_{(s)}$$

$$CH_{4(g)} + Cl_{2(g)} \xrightarrow{hv} CH_3Cl_{(l)} + HCl_{(g)}$$

Chlorine reacts with many covalent compounds to form addition products such reactions are called addition reaction.

$$CO_{(g)} + Cl_{2(g)} \xrightarrow{heat} COCl_{2(g)}$$ **Carbonyl chloride (Phosgene gas)**

$$SO_{2(g)} + Cl_{2(g)} \xrightarrow{heat} SO_2Cl_{2(g)}$$ **(Sulphuryl chloride)**

$$\underset{\text{Ethene}}{CH_2=CH_{2(g)}} + Cl_{2(g)} \xrightarrow{heat} \underset{\text{1, 2-dichloro ethane (Vicinal dichloride)}}{ClCH_2-CH_2Cl_{(g)}}$$

## (1) HYDROCHLORIC ACID (HCl)

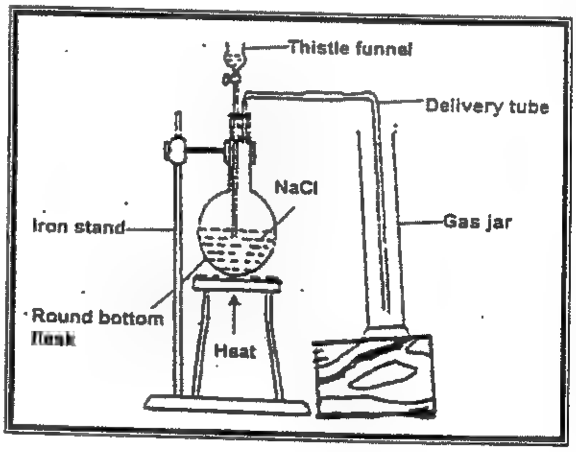
Hydrochloric acid is also called acid of salt. It is a mineral acid.

### Laboratory preparation:

In the laboratory, Hydrochloric acid is prepared by the action of concentrated Sulphuric acid ($H_2SO_4$) with sodium chloride (NaCl).

$$NaCl_{(s)} + H_2SO_{4\,(conc)} \xrightarrow{heat} NaHSO_{4(s)} + HCl_{(g)}$$

In this method, common salt (NaCl) is placed in a round bottom flask, fitted with a thistle funnel and a delivery tube. Concentrated $H_2SO_4$ is added from the thistle funnel over common salt. The mixture is heated then **hydrogen chloride gas** (HCl) is liberated, which is collected through the delivery tube in gas jar by **the upward displacement of air.**




**Hydrogen chloride gas** (HCl) is highly soluble in water so the aqueous solution of hydrogen chloride gas is called **Hydrochloric acid.**

### Industrial Preparation:

Hydrochloric acid is commercially prepared by the direct combination of hydrogen and chlorine gas as a result **hydrogen chloride gas** is formed.

$$H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)} \quad \Delta H = -44\ KJ/mol$$

This reaction is exothermic so the hot gas is then mixed in water as a result **Hydrochloric acid** is formed.

Hydrochloric acid is also prepared by the reaction of phosphorous tri chloride with water.

$$PCl_{3(l)} + 3H_2O_{(l)} \longrightarrow \underset{\text{Phosphorous acid}}{H_3PO_{3(aq)}} + \underset{\text{Hydrogen chloride}}{3HCl_{(g)}}$$

When Hydrogen chloride gas is mixed in water then **Hydrochloric acid** is formed.

## PHYSICAL PROPERTIES:

(i) Hydrogen chloride is a colourless gas with strong acidic odour and sour taste.
(ii) It is highly soluble in water to form hydrochloric acid.
(iii) It is slightly heavier than air.

## CHEMICAL PROPERTIES (REACTIONS):

### (i) Reaction with Water:

Hydrochloric acid is a strong acid. It is mono protic acid. It ionizes in water as:

$$HCl_{(aq)} + H_2O_{(l)} \rightleftharpoons \underset{\text{Oxonium or Hydronium ion}}{H_3O^+_{(aq)}} + Cl^-_{(aq)}$$

### (ii) Reaction with Alkalis:

Hydrochloric acid reacts with alkalis (NaOH solution or KOH solution) to produce salt and water. This reaction is called neutralization.

$$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$$
$$KOH_{(aq)} + HCl_{(aq)} \longrightarrow KCl_{(aq)} + H_2O_{(l)}$$

### (iii) Reaction with Ammonia:

Hydrochloric acid reacts with ammonia ($NH_3$) to produce white fumes of ammonium chloride ($NH_4Cl$).

$$NH_3 + HCl \longrightarrow NH_4Cl \text{ (White fumes)}$$

### (iv) Reaction with Metals:

Dilute Hydrochloric acid reacts with metals like Mg, Zn, Al, etc. then Hydrogen gas is liberated along with the salts.

$$Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2(aq)} + H_{2(g)}$$
$$Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$$
$$2Al_{(s)} + 6HCl_{(aq)} \longrightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$$

### (v) Reaction with Metal carbonates and Metal bicarbonates:

Dilute Hydrochloric acid reacts with Metal carbonates and bicarbonates then $CO_2$ gas is liberated along with the salts.

$$Na_2CO_{3(s)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$
$$CaCO_{3(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$
$$NaHCO_{3(s)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$

### (vi) Reaction with $AgNO_3$ and $Pb(NO_3)_2$:

Dilute Hydrochloric acid reacts with Silver nitrate and Lead nitrate then their white precipitate are formed.

$$AgNO_{3(aq)} + HCl_{(aq)} \longrightarrow \underset{\text{White precipitate}}{AgCl_{(s)}} + HNO_{3(aq)}$$
$$Pb(NO_3)_{2(aq)} + 2HCl_{(aq)} \longrightarrow \underset{\text{White precipitate}}{PbCl_{2(s)}} + 2HNO_{3(aq)}$$

## APPLICATIONS (USES) OF HCl:

(i) Hydrochloric acid is used for the pickling of iron and steel to remove the rust from the metal surface.

(ii) It is used in the manufacture of dyes, plastics, medicine, rubber, etc.

(iii) It is used as chemical reagent in the laboratory.

(iv) It is used to remove $CaCO_3$ deposits from sanitary wares and floors.

## (-) BLEACHING POWDER:

It is a compound of chlorine with calcium and oxygen. The chemical name is calcium oxychloride and commonly called bleaching powder.

Professor Odling suggested the formula of bleaching powder as $Ca(OCl)Cl$ or $CaOCl_2$.

### (i) Laboratory Preparation:

In the laboratory, bleaching powder is prepared by the reaction of lime water (slaked lime) or calcium hydroxide $Ca(OH)_2$ with chlorine.

$$Ca(OH)_{2(aq)} + Cl_{2(g)} \longrightarrow \underset{\text{Bleaching powder}}{Ca(OCl)Cl_{(s)}} + H_2O_{(l)}$$

### (ii) Industrial Preparation:

In the industry, bleaching powder is prepared by **Hasen Clever process**. The plant consists of four iron cylinders 2 to3 meter long. Slaked lime which is showered from top of the cylinders and chlorine gas is passed from the bottom of the cylinder. Bleaching powder is removed from the cylinder.

$$Ca(OH)_{2(aq)} + Cl_{2(g)} \longrightarrow \underset{\text{Bleaching powder}}{Ca(OCl)Cl_{(s)}} + H_2O_{(l)}$$

## CHEMICAL PROPERTIES:

### (i) Reaction with Water:

Bleaching powder is used with water, and then $Cl_2$ gas is liberated.

$$Ca(OCl)Cl_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)} + Cl_{2(g)}$$

### (ii) Reaction with Strong Acids:

Bleaching powder reacts with strong acids like $HCl$ to liberate $Cl_2$ gas.

$$Ca(OCl)Cl_{(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + Cl_{2(g)} + H_2O_{(l)}$$

### (iii) Reaction with Weak Acids ($H_2O + CO_2 = H_2CO_3$):

Bleaching powder reacts with carbonic acid then **hypochlorous acid ($HOCl$)** is formed.

$$2Ca(OCl)Cl_{(s)} + CO_{2(g)} + H_2O \longrightarrow CaCO_{3(s)} + CaCl_{2(aq)} + 2HOCl_{(aq)}$$

### (iv) Reaction with Ammonia:

Bleaching powder reacts with ammonia then $N_2$ gas is liberated.

$$3Ca(OCl)Cl_{(s)} + 2NH_{3(g)} \longrightarrow 3CaCl_{2(aq)} + 3H_2O_{(l)} + N_{2(g)}$$

(3) (a) What are halogens? Why are they placed in VII A group in the periodic table? Describe the state of each member of the family and also their colours.
**Answer on page# 3**

(b) What are the sources of halogens? Describe the importance of $Cl_2$, $Br_2$ and $I_2$ in our daily life.
**Answer on page# 4 and 5**

(4) (a) How is chlorine prepared in the laboratory?
**Answer on page# 5**

(b) Describe the commercial preparation of chlorine by the electrolysis of aqueous NaCl solution in Nelson's cell.
**Answer on page# 6**

(c) What happens when chlorine reacts with: (i) Zn (ii) $H_2S$ (iii) CO (iv) P (v) $FeCl_2$ (vi) $H_2O$. Give reactions and equations.
**Answer on page# 8 and 9**

(d) Discuss the uses of chlorine.
**Answer on page# 5**

(5) (a) Give the preparation of hydrogen chloride (HC*l*) in the laboratory by the action of conc. $H_2SO_4$ over common salt (NaC*l*).
**Answer on page# 9**

(b) How does hydrogen chloride manufacture commercially by direct combination of $H_2$ and $Cl_2$ gases.
**Answer on page# 10**

(c) What is the action of hydrochloric acid (HC*l*) on?
(i) NaOH (ii) $NaHCO_3$ (iii) $Pb(NO_3)_2$
(iv) $MnO_2$ (v) $AgNO_3$
**Answer on page# 10 and 11**

(6) (a) What is bleaching powder? How is it manufactured commercially by Hasenclever process? Give the uses of bleaching powder.
**Answer on page# 11 and 12**

(b) What is the action of bleaching powder over?
(i) Water (ii) HC*l*
(iii) $H_2CO_3$ (weak acid) (iv) Ammonia ($NH_3$)
**Answer on page# 11 and 12**

(7) (a) Describe silver nitrate test for the presence of $Cl^-$ ion in a salt of chloride. Give the reaction.
**Answer on page# 12**

(b) Identify the following:
(i) A pale green gas that dissolves in aqueous NaOH solution give a solution used as a bleach. **($Cl_2$ gas)**
(ii) A gas with pungent smell, acidic taste, highly soluble in water to form a strong acid. **($Cl_2$ gas)**
(iii) White amorphous solid which reacts with water to liberate chlorine gas. **(Bleaching Powder)**
(iv) The deficiency of this leads to the enlargement of thyroid gland. **($I^-$ ions)**
(v) A pale yellow gas, very unstable in water. **($F_2$)**
(vi) A non-sticking material, having very low coefficient of heat. **(Teflon)**

## APPLICATIONS (USES) OF HCl:

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(ii) It is used in the manufacture of dyes, plastics, medicine, rubber, etc.

(iii) It is used as chemical reagent in the laboratory.

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## (2) BLEACHING POWDER:

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### (i) Laboratory Preparation:

In the laboratory, bleaching powder is prepared by the reaction of lime water (slaked lime) or calcium hydroxide $Ca(OH)_2$ with chlorine.

$$Ca(OH)_{2(aq)} + Cl_{2(g)} \longrightarrow \underset{\text{Bleaching powder}}{Ca(OCl)Cl_{(s)}} + H_2O_{(l)}$$

### (ii) Industrial Preparation:

In the industry, bleaching powder is prepared by **Hasen Clever process**. The plant consists of four iron cylinders 2 to3 meter long. Slaked lime which is showered from top of the cylinders and chlorine gas is passed from the bottom of the cylinder. Bleaching powder is removed from the cylinder.

$$Ca(OH)_{2(aq)} + Cl_{2(g)} \longrightarrow \underset{\text{Bleaching powder}}{Ca(OCl)Cl_{(s)}} + H_2O_{(l)}$$

## CHEMICAL PROPERTIES:

### (i) Reaction with Water:

Bleaching powder is used with water, and then $Cl_2$ gas is liberated.

$$Ca(OCl)Cl_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)} + Cl_{2(g)}$$

### (ii) Reaction with Strong Acids:

Bleaching powder reacts with strong acids like $HCl$ to liberate $Cl_2$ gas.

$$Ca(OCl)Cl_{(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + Cl_{2(g)} + H_2O_{(l)}$$

### (iii) Reaction with Weak Acids ($H_2O + CO_2 = H_2CO_3$):

Bleaching powder reacts with carbonic acid then **hypochlorous acid ($HOCl$)** is formed.

$$2Ca(OCl)Cl_{(s)} + CO_{2(g)} + H_2O \longrightarrow CaCO_{3(s)} + CaCl_{2(aq)} + 2HOCl_{(aq)}$$

### (iv) Reaction with Ammonia:

Bleaching powder reacts with ammonia then $N_2$ gas is liberated.

$$3Ca(OCl)Cl_{(s)} + 2NH_{3(g)} \longrightarrow 3CaCl_{2(aq)} + 3H_2O_{(l)} + N_{2(g)}$$

## APPLICATIONS (USES):

(i) Bleaching powder is used for sterilizing of drinking water and disinfecting drains and sewers.

(ii) It is used for bleaching of cotton, linen and paper pulp.

(iii) It is used for the preparation of $Cl_2$ gas which is a powerful oxidizing agent.

## TESTS FOR HALIDE IONS (Silver Nitrate Test):

All common metallic halides, such as NaCl, KBr, $MgI_2$ are soluble in water except **halides of Ag and Pb**. For the detection of $Cl^-$, $Br^-$, and $I^-$ ions, silver nitrate test is performed which gives the precipitates of AgCl, AgBr and AgI.

For this purpose, the aqueous solutions are treated with the solution of silver nitrate ($AgNO_3$) to give the specific coloured precipitate.

| EXPERIMENT | OBSERVATION | INFERENCE |
|---|---|---|
| Original solution + $AgNO_3$ | (i) If white ppt. of **AgCl** is formed which is soluble in $NH_3$ solution. | $Cl^-$ is present |
| | (ii) If light yellow or cream ppt. of **AgBr** is formed which is partially soluble in $NH_3$ solution. | $Br^-$ is present |
| | (iii) If bright yellow ppt. of AgI is formed which is insoluble in $NH_3$ solution. | $I^-$ is present |

### Reactions:

(i) $NaCl_{(aq)} + AgNO_{3(aq)} \longrightarrow \underset{\text{White ppt}}{AgCl_{(s)}} + NaNO_{3(aq)}$

(ii) $NaBr_{(aq)} + AgNO_{3(aq)} \longrightarrow \underset{\text{Light yellow ppt}}{AgBr_{(s)}} + NaNO_{3(aq)}$

(iii) $NaI_{(aq)} + AgNO_{3(aq)} \longrightarrow \underset{\text{Bright yellow ppt}}{AgI_{(s)}} + NaNO_{3(aq)}$



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## EXERCISE

(1)(a) Fill in the blanks:

(i) *Bromine* is the dark brown volatile liquid.

(ii) *Iodine* is the black shining low melting point sublime solid.

(iii) *Fluorine* can replace all other halogens from the solutions of their salts.

(iv) $I_2$ dissolved in alcohol is called *Tincture of Iodine*.

(v) ... gas is liberated by the action of *Bleaching powder* over water.

**(b) Write True or False in the following statements:**

(i) In the electrolysis of sodium chloride solution, chloride ions are discharged at the anode. [False]

(ii) Hydrochloric acid reacts with metals to release $H_2$ gas. [True]

(iii) Bleaching powder is a powerful reducing agent. [False]

(iv) All halogens contain six electrons in the outer shell. [False]

(v) Astatine the last member of halogens is unstable and radioactive. [True]

(vi) $Br_2$ can displace chlorine from $KCl$. [False]

**(c) Pick up the correct answers:**

(i) In the process of electrolysis:

(a) Oxidation takes place at cathode.

(b) Reduction takes place at anode.

(c) ***Cations are discharged at cathode.***

(d) Anions are discharged at cathode.

(ii) Which one of the following will release chlorine from hydrochloric acid?

(a) Na (b) ***$MnO_2$*** (c) KOH (d) $CuSO_4$

(iii) When chlorine atom combines with hydrogen atoms, which type of the bond is formed?

(a) Ionic bond (b) Co ordinate covalent

(c) ***Polar covalent*** (d) Non-Polar covalent.

(iv) Chlorine gas prepared in the laboratory is collected in the gas jar by:

(a) Upward displacement of water

(b) ***Upward displacement of air***

(c) Downward displacement of air

(d) Downward displacement of water.



**(2) Complete the following reactions:**

(i) $MnO_{2(s)} + 4HCl_{(conc)} \longrightarrow MnCl_{2(s)} + 2H_2O_{(l)} + Cl_{2(g)}$

(ii) $2NaHg_{(l)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)} + 2Hg_{(l)}$

(iii) $2KI_{(s)} + Cl_{2(g)} \longrightarrow 2KCl_{(s)} + I_{2(s)}$

(iv) $6NaOH_{(aq)} + 3Cl_{2(g)\,(excess)} \xrightarrow{hot} 5NaCl_{(s)} + NaClO_{3(aq)} + 3H_2O_{(l)}$

(v) $AgNO_{3(aq)} + HCl_{(aq)} \longrightarrow AgCl_{(s)} + AgNO_{3(aq)}$

(vi) $Ca(OCl)Cl_{(s)} + 2HCl_{(aq)} \longrightarrow CaCl_{2(s)} + Cl_{2(g)} + H_2O_{(l)}$

(vii) $KBr_{(aq)} + AgNO_{3(aq)} \longrightarrow KNO_{3(aq)} + AgBr_{(s)}$

(viii) $K_2Cr_2O_7 + 14HCl_{(conc)} \longrightarrow 2KCl_{(s)} + 2CrCl_{3(s)} + 7H_2O_{(l)} + 3Cl_{2(g)}$

(3) (a) What are halogens? Why are they placed in VII A group in the periodic table? Describe the state of each member of the family and also their colours.

**Answer on page# 3**

(b) What are the sources of halogens? Describe the importance of $Cl_2$, $Br_2$ and $I_2$ in our daily life.

**Answer on page# 4 and 5**

(4) (a) How is chlorine prepared in the laboratory?

(b) Describe the commercial preparation of chlorine by the electrolysis of aqueous NaCl solution in Nelson's cell.

**Answer on page# 6**

(c) What happens when chlorine reacts with: (i) Zn (ii) $H_2S$ (iii) CO (iv) P (v) $FeCl_2$ (vi) $H_2O$. Give reactions and equations.

**Answer on page# 8 and 9**

(d) Discuss the uses of chlorine.

**Answer on page# 5**

(5) (a) Give the preparation of hydrogen chloride (HC*l*) in the laboratory by the action of conc. $H_2SO_4$ over common salt (NaC*l*).

**Answer on page# 9**

(b) How does hydrogen chloride manufacture commercially by direct combination of $H_2$ and $Cl_2$ gases.

**Answer on page# 10**

(c) What is the action of hydrochloric acid (HC*l*) on?

(i) NaOH (ii) $NaHCO_3$ (iii) $Pb(NO_3)_2$

(iv) $MnO_2$ (v) $AgNO_3$

**Answer on page# 10 and 11**

(6) (a) What is bleaching powder? How is it manufactured commercially by Hasenclever process? Give the uses of bleaching powder.

**Answer on page# 11 and 12**

(b) What is the action of bleaching powder over?

(i) Water (ii) HC*l*

(iii) $H_2CO_3$ (weak acid) (iv) Ammonia ($NH_3$)

**Answer on page# 11 and 12**

(7) (a) Describe silver nitrate test for the presence of $Cl^-$ ion in a salt of chloride. Give the reaction.

**Answer on page# 12**

(b) Identify the following:

(i) A pale green gas that dissolves in aqueous NaOH solution give a solution used as a bleach. ($Cl_2$ gas)

(ii) A gas with pungent smell, acidic taste, highly soluble in water to form a strong acid. (**$Cl_2$ gas**)

(iii) White amorphous solid which reacts with water to liberate chlorine gas. (**Bleaching Powder**)

(iv) The deficiency of this leads to the enlargement of thyroid gland. (**$I^-$ ions**)

(v) A pale yellow gas, very unstable in water. (**$F_2$**)

(vi) A non-sticking material, having very low coefficient of heat. (**Teflon**)

SESSION
2016-2017

# CLASS-IX

# CHEMISTRY

## Chapter # 16

## METALS AND THEIR EXTRACTION

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# METALS AND THEIR EXTRACTION 16

## METALS AND NON-METALS:

Elements in the periodic table are classified mainly as metals and non-metals. In early days, metals were identified from non-metals by their physical characteristics. [illegible]

### (1) Physical differences between Metals and Non-Metals:

| Metals | Non Metals |
|---|---|
| All metals are found in **solid** state with **high** Melting and Boiling points. Except Mercury (Hg) which is liquid. | Non metals are found in **solid** and **gas** state with **low** Melting and Boiling points. Except Bromine (Br) which is liquid. |
| They have **shiny** surfaces (luster) and can be polished. | They have **no luster** and can not be polished. |
| They are **sonorous** because they produce sound by hitting on their surfaces. | They are **not sonorous** because they do not produce sound by hitting on their surfaces. |
| They are **malleable** and **ductile** because they can be converted into sheets and wires. | They are **neither** malleable **nor** ductile. They are brittle. |
| They are **good conductor** of heat and electricity due to free electrons. They are conductors. | They are **bad conductor** of heat and electricity because they do not have free electrons. They are insulators. |
| Iron (Fe), Copper (Cu), Zinc (Zn), Aluminium (Al). Chromium (Cr) are some metals having relatively **high density**. | Sulphur (S), Carbon (C), Oxygen ($O_2$), Nitrogen ($N_2$) and Chlorine ($Cl_2$) are some non metals having relatively **low density**. |

## (2) Chemical Differences between Metals and Non Metals:

| Metals | Non Metals |
|---|---|
| Metal oxides are **basic** in nature when dissolved in water they form **alkaline** solution which turns red litmus blue. | Non metal oxides are **acidic** in nature when dissolved in water they form **acidic** solution that turn blue litmus red. |
| Metals are donor of electrons (reducing agents). They form cations because they are highly electropositive in nature.<br>$Na \rightarrow Na^{+} + \bar{e}$<br>2,8,1   2,8<br>$Al \rightarrow Al^{3+} + 3[\bar{e}]$<br>2,8,3   2,8 | Non metals are **acceptor** of electrons (oxidizing agents). They form anions because they are highly electronegative in nature.<br>$Cl + \bar{e} \rightarrow Cl^{-}$<br>2,8,7   2,8,8<br>$N + 3\bar{e} \rightarrow N^{3-}$<br>2,5   2,8 |
| Metallic Chlorides are electrovalent **(ionic compounds)**. They are Crystalline solids and good electrolytes. They are soluble and they ionize in water.<br>$Na + 1/2Cl_2 \rightarrow Na^{+}Cl^{-}_{(s)}$<br>$NaCl_{(s)} + H_2O \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$ | Non Metallic Chlorides are **covalent compounds**. They are amorphous solids or polar liquids. They hydrolyzed in water.<br>$2P_{(s)} + Cl_{2(g)} \rightarrow PCl_{3(l)}$<br>$PCl_3 + 3H_2O \rightarrow H_3PO_3 + 3HCl$ |
| Na, K and Ca react with Hydrogen to form ionic hydrides by the transfer of electrons such as $Na^{+}H^{-}, K^{+}H^{-}, Ca^{2+}H_2^{2-}$. | Non metals react with Hydrogen to form covalent hydrides by the sharing of electrons such as $NH_3$, $H_2S$, $HCl$, etc. |
| Metals react with dilute acid to liberate $H_2$ gas forming their salts by the loss of electrons.<br>$Zn + 2H_2SO_{4(aq)} \rightarrow ZnSO_{4(aq)} + H_{2(g)}$ | Non metals do not react with dilute acid but they react with concentrated acid to form non metallic oxides.<br>$S + 2H_2SO_{4(conc)} \xrightarrow{Hot} 3SO_{2(g)} + 2H_2O$ |

## MINERALS:

The naturally occurring compounds which are obtained from earth crust are called Minerals.

## ORES:

The minerals which are used commercially for the preparation or extraction of metals are called Ores.

## GANGUE:

Ores consist of minerals and some impurities (like rock materials) are called Gangue.

## OCCURRENCE OF IRON:

Iron has been known and used by mankind for very long time. It is one of the best known metals in the world because of its great industrial importance.

Iron is the **fourth** (4th) most abundant metal found in the earth crust. Iron is generally found in the combined states. The most common minerals or ores of Iron are:

(i) Haematite : $Fe_2O_3$
(ii) Magnetite : $Fe_3O_4$
(iii) [illegible] pyrite : $FeS_2$
(iv) Siderite : $FeCO_3$
(v) Limonite : $Fe_2O_3 . 3H_2O$ (Hydrated)

In Pakistan, large deposits of high grade iron ores are found in Chitral, Kohistan and Baluchistan. Presently these ores are not commercially utilized in Pakistan.

## OCCURRENCE OF COPPER:

Copper has been known and used by mankind since the **Bronze Age.** The ancient Egyptians, Romans and Greeks used copper for their metal works. The most common minerals or ores of Copper are:

| | | | | |
|---|---|---|---|---|
| (i) | Copper pyrite | : | $CuFeS_2$ | |
| (ii) | Copper glance | : | $CuS$ | |
| (iii) | Cuperite | : | $Cu_2O$ | |
| (iv) | Chalcocite | : | $Cu_2S$ | |
| (v) | Malachite | : | $CuCO_3 . Cu(OH)_2$ | (green colour) |
| (vi) | Azurite | : | $[2CuCO_3 . Cu(OH)_2]$ | (blue colour) |

In Pakistan, deposits of copper are found in Baluchistan. The most important ore of copper is copper pyrite ($CuFeS_2$).

## OCCURRENCE OF ALUMINIUM:

Aluminium is the **third** (3rd) most abundant element after oxygen and silicon found in the earth's crust. It is the most abundant metal present in the earth's crust. The important minerals or ores of Aluminium are:

| | | | | |
|---|---|---|---|---|
| (1) OXIDE ORES | (i) | Bauxite | : | $Al_2O_3 . nH_2O$ ($Al_2O_3 . 2H_2O$) |
| | (ii) | Diaspore | : | $Al_2O_3 . H_2O$ |
| | (iii) | Corrundum | : | $Al_2O_3$ |
| (2) FLUORIDE ORE | (i) | Cryolite | : | $Na_3AlF_6$ |
| (3) SILICATE ORES | (i) | Kaolin | : | $Al_2O_3 . 2SiO_2 . 2H_2O$ |
| | (ii) | Potash Feldspar | : | $K_2O . Al_2O_3 . 6SiO_2$ |
| | (iii) | Potash Mica | : | $K_2O . 3Al_2O_3 . 6SiO_2 . 2H_2O$ |
| (4) SULPHATE ORE | (i) | Alunite | : | $K_2SO_4 . Al_2(SO_4)_3 . 4Al(OH)_3$ |

In Pakistan, deposits of aluminium are found near the village Khilla; Muzaffarabad (Azad Kashmir), village Salhan of Tehsil Kohli, near Rawalpindi at Margalla hills, Surge of District Attock and in Tharparkar and Dadu Districts of Sindh.

## OCCURRENCE OF CHROMIUM:

Chromium is a silvery white metal and is well known for its anti corrosion and [illegible]

Chromite ore is found in Baluchistan and in Malakand at NWFP.

## METALLURGY:

The majority metals are found in nature in the combined states with other chemical substances, known as minerals. The extraction of metal from its ore is termed as metallurgy. Thus metallurgy is the method of extracting metals from their natural sources (minerals or ores).

## METALLURGY OF IRON (EXTRACTION OF IRON):

Iron is extracted from Haematite ($Fe_2O_3$) or Limonite ($Fe_2O_3 . 3H_2O$) ores.

## RAW MATERIALS:

(i) Haematite ($Fe_2O_3$) or Limonite ($Fe_2O_3 . 3H_2O$)

(ii) Coke (carbon)

(iii) Lime stone $CaCO_3$ (calcium carbonate)

## WORKING:

The crushed **iron ore** is mixed with **coke (C)** and **lime stone ($CaCO_3$)** which are fed from the top of the furnace, while a blast of hot air is introduced into it from the bottom through small pipes known as **Tuyeres**.

The temperature inside the furnace varies from about 2000° C near the bottom to about 400° C at the top. The hot air oxidizes the coke (C) to carbon dioxide ($CO_2$) with the liberation of lot of heat.

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \quad ; \quad \Delta H = -394 \text{ KJ/mol}$$

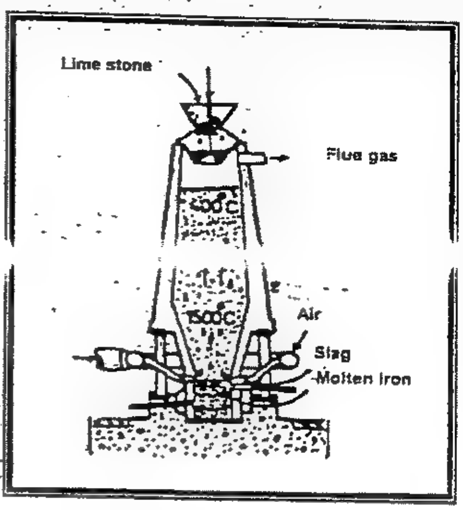
The reaction is highly exothermic so Carbon dioxide ($CO_2$) gas in the furnace reacts with more coke then carbon monoxide (CO) gas is formed.

$$CO_{2(g)} + C_{(s)} \longrightarrow 2CO_{(g)} \quad ; \quad \Delta H = +173 \text{ KJ/mol}$$

Carbon monoxide (CO) gas reacts with the iron oxide ore to form iron metal.

$$Fe_2O_{3(s)} + 3CO_{(g)} \longrightarrow 2Fe_{(l)} + 3CO_{2(g)}$$

The lime stone ($CaCO_3$) decomposes at high temperature to produce calcium oxide (CaO) reacts with silica ($SiO_2$) and aluminium oxide ($Al_2O_3$) which are present as impurities to form calcium silicate ($CaSiO_3$) and calcium aluminate $Ca(AlO_2)_2$.




$$CaCO_{3(s)} \xrightarrow{\text{high temp}} CaO_{(s)} + CO_{2(g)}$$

(i) $CaO + SiO_2 \longrightarrow CaSiO_{3(l)}$

(ii) $CaO + Al_2O_3 \longrightarrow Ca(AlO_2)_{2\,(l)}$

The mixture of $CaSiO_3$ and $Ca(AlO_2)_2$ is known as **Slag**. The molten free iron runs downward to the bottom of the furnace. The slag floats on top of the molten iron and easily be removed.

The molten iron from the blast furnace is pour into sand moulds where it cools down to solid blocks called **Pig Iron.**

Slag is a useful by-product. It is used as a road making material, for cement manufacturing and for making light weight building materials.

The gas leaving the furnace is known as **Flue Gas.** It contains nitrogen ($N_2$), carbon monoxide (CO), carbon dioxide ($CO_2$) and fine carbon (C) particles. The emission of flue gas is a source of environmental pollution.

**Pig iron** is hard but brittle and melts at **1200°C**. Pig iron contains some impurities such as silicon, sulphur, phosphorous and manganese.

## TYPES OF IRON:

### (1) Pig Iron:

The impure iron which is obtained directly from the furnace is called **Pig Iron**. It contains upto 4% carbon (C) along with silicon (Si), sulphur (S), phosphorous (P) and manganese (Mn) in different proportions. The presence of these impurities lowers the melting point of iron from **1530°C to 1200°C.**

### (2) Cast Iron:

The iron which is obtained by the re-melted the pig iron and then cooled in moulds of required shapes is called **Cast Iron.** Cast iron has a slightly lower percentage of impurities than pig iron and almost has the same physical properties.

**Properties:** It is hard but brittle and can not be welded.

**Uses:** It is used for making tools, lamp posts, gates, railings. engine blocks, the base of Bunsen burners, etc.

### (3) Wrought Iron:

The purest form of iron is **Wrought Iron.** It contains only about 0.1% carbon. Wrought iron is obtained by heating cast iron in a furnace with haematite ($Fe_2O_3$). During this process, carbon and sulphur are oxidized and are removed as $CO_2$ and $SO_2$ respectively.

$$2Fe_2O_{3(s)} + 3C_{(s)} \longrightarrow 4Fe_{(l)} + 3CO_{2(g)}$$

$$2Fe_2O_{3(s)} + 3S_{(s)} \longrightarrow 4Fe_{(l)} + 3SO_{2(g)}$$

At the same time phosphorous and silicon present are converted into phosphate and silicates of iron which can be removed as a slag from the semi-molten mass of iron.

**Properties:** It is tough and malleable. It can be shaped by hammering at about 500°C to 1000°C before its melting point. It can easily be welded.

**Uses:** It is used for making nails, chains, iron rods, sheets, swords, etc.

About 90% of the pig iron is converted into steel. Steel is an alloy of iron with carbon (C) and other elements such as manganese (Mn), nickel (Ni), chromium (Cr), tungsten (W) and vanadium (V).

### The Comparison of Impurities

| Impurity | Impurity in pig Iron | Impurity in steel |
|---|---|---|
| Carbon | 3% – 4% | 0.15% |
| Silicon | 1% – 2% | 0.03% |
| Phosphorous | 0.05 – 1.5% | 0.05% |
| Manganese | 0.5 – 1.0% | 0.5% |
| Sulphur | 0.05 – 0.1% | 0.05% |

There are several methods of making steel. Following are the important methods:

(1) The basic oxygen process

(2) Open hearth process

(3) The electric arc process.

However, they are all based on the same general principle of removing the impurities of C, Si, S, P and Mn from the molten pig iron and to obtain steel of desired compositions.

The steel obtained is very hard and brittle so the removal of brittleness and to increase tensile strength, the steel is re-heated to certain temperature carefully and allowed to cool slowly. This process is known as Tempering.

Alloy steels are obtained by the presence of Nickel (Ni) and Chromium (Cr). Stainless steel gives better resistance to corrosion or rusting and it is used in making cutleries, scissors, surgical instruments and machineries. The presence of cobalt (Co) gives highly magnetic steel, used for making permanent magnets. Tungsten (W) gives very hard steel for making cutting and drilling tools.

## Some common Stainless Steel:

There are three main types of stainless steels which have different percentage of metals are as follows:

(1) Stainless steel containing 13% Cr and 0.1 - 0.4% C

(2) Stainless steel containing 17% Cr and 2% Ni

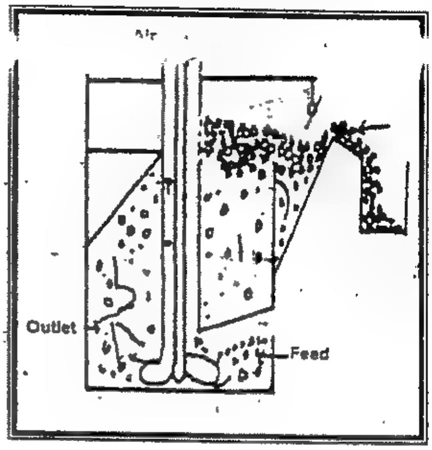
(3) Stainless steel containing 18% Cr and 6% Ni

# METALLURGY OF COPPER (EXTRACTION OF COPPER):

Copper metal is usually extracted from its sulphide ore, such as copper pyrite ($CuFeS_2$) which contains about 6% copper.

The extraction of copper from copper pyrite involves the following processes:

## (1) Concentration of the Ore:




In this process, the pyrite ore is first concentrated by **Froth Floatation Process**. In this process the ore is crushed and is mixed with water and pine oil. Air is blown into the mixture, oil forms froth with sulphide ore, which floats on the surface. The gangue (impurities) settles down. The froth along with the mineral particles is skimmed off and is dried to get concentrated ore. The gangue (impurities) particles are left behind.

## (2) Roasting:

The concentrated ore is then roasted on an open hearth furnace in air. Part of sulphur and other impurities are burnt off and are removed as their oxides.

$$4CuFeS_{2(s)} + 5O_{2(g)} \xrightarrow{\text{roasted}} 2Cu_2S_{(s)} + 2FeO_{(s)} + 2FeS_{(s)} + 4SO_{2(g)}$$

## (3) Smelting:

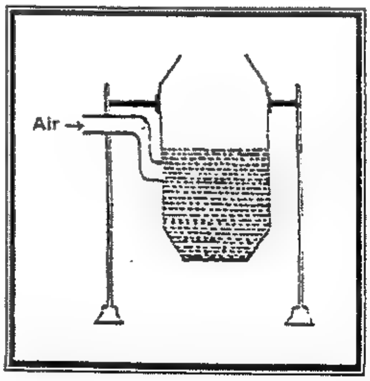
The roasted ore is then sent into a blast furnace together with a little coke and silica ($SiO_2$). In this process, iron sulphide is changed into iron oxide which combines with silica to form iron silicate ($FeSiO_3$). The slag is removed which floats on the surface.

$$2FeS_{(s)} + 3O_{2(g)} \longrightarrow 2FeO_{(s)} + 2SO_{2(g)}$$

$$FeO_{(s)} + SiO_{2(s)} \longrightarrow FeSiO_{3(l)} \quad \text{(slag)}$$

The molten mixture below the slag contains cuprous sulphide ($Cu_2S$) with some ferrous sulphide (FeS) known as Matte.

## (4) Reduction:




The matte ($Cu_2S$ with some unreacted FeS) is carried out to a converter called **Bessemer Converter** where it is treated with some silica by blowing hot air. The iron sulphide (FeS) is changed to FeO, forming **slag** ($FeSiO_3$) with **silica** ($SiO_2$). The hot air converts $Cu_2S$ partially to $Cu_2O$ which then reacts with remaining $Cu_2S$ to give **molten copper.**

| | | | | | | |
|---|---|---|---|---|---|---|
| $2FeS_{(s)}$ | + | $3O_{2(g)}$ | $\longrightarrow$ | $2FeO_{(s)}$ | + | $2SO_{2(g)}$ |
| $FeO_{(l)}$ | + | $SiO_{2(s)}$ | $\longrightarrow$ | $FeSiO_{3(l)}$ | | |
| $2Cu_2S_{(l)}$ | + | $3O_{2(g)}$ | $\longrightarrow$ | $2Cu_2O_{(l)}$ | + | $2SO_{2(g)}$ |
| $2Cu_2O_{(l)}$ | + | $Cu_2S_{(l)}$ | $\longrightarrow$ | $6Cu_{(l)}$ | + | $SO_{2(g)}$ |

is known as **Blister Copper**. The blisters are produced during solidification on cooling due to the escape of $SO_2$ gas. Blister copper is about 98% pure copper.

## (5) Refining of Blister Copper:

Blister copper contains **Fe, Zn, Pb, Ag** and **Au** as impurities which reduce the conductivity of copper so blister copper is refined by the electrolytic process.

In this process, blocks of **impure copper** (blister copper) are used as **anode** and very thin sheet of **pure copper** act as **cathode**. The anode and cathode are suspended in acidified copper sulphate solution ($CuSO_4$).

When current is passed through the cell then the **copper ions** from the solution deposited at **cathode** and **impure copper anode dissolved** in the solution while impurities are remained below the anode which is called **anode mud**.

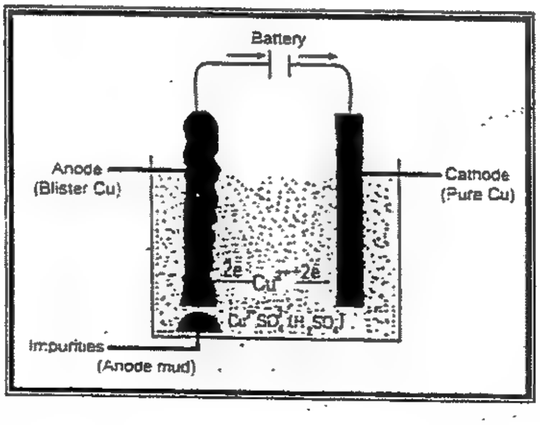
### Reaction:

At Anode: $\underset{\text{Blister copper}}{Cu_{(s)}} \longrightarrow Cu^{2+}_{(aq)} + 2e^-$

At Cathode: $Cu^{2+}_{(aq)} + 2e^- \longrightarrow \underset{\text{Pure copper metal}}{Cu_{(s)}}$

The electrically refined copper is 100% pure.



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# METALLURGY OF ALUMINIUM (EXTRACTION OF ALUMINIUM):

Aluminium metal is obtained by its bauxite ore. The industrial process invented in 1886 by **Hall** and **Beroult**.

This process involved two stages:

## (1) Purification of Bauxite:

The bauxite ore contains major impurities of ferric oxide ($Fe_2O_3$) and silica ($SiO_2$). In this step, the bauxite ore is grinded and crushed to finely divided bauxite ore. It is then heated with concentrated caustic soda (NaOH) solution as a result aqueous solution of **Sodium Aluminate** ($NaAlO_2$) is formed. Since the impurities are insoluble and can be removed by filtration.

$$\underbrace{Al_2O_3 . 2H_2O_{(s)}}_{\text{Bauxite}} + 2NaOH_{(aq)} \longrightarrow \underbrace{2NaAlO_{2(aq)}}_{\text{Sodium aluminate}} + 3H_2O_{(l)} + \text{impurities}$$

The filtrate which is sodium aluminate is hydrolyzed with excess of water to precipitate aluminium hydroxide which is filtered, washed and dried.

$$2NaAlO_2 + 4H_2O \longrightarrow 2Al(OH)_{3(s)} + 2NaOH_{(aq)}$$

$Al(OH)_3$ is heated up to 1500 °C which gives pure alumina ($Al_2O_3$).

$$2Al(OH)_{3(s)} \xrightarrow{1500^\circ C} \underbrace{Al_2O_{3(s)}}_{\text{Pure alumina}} + 3H_2O_{(g)}$$

## (2) Electrolysis of Pure Alumina:

The electrolysis of pure alumina is carried in a steel tank lined inside with graphite which acts as cathode, while anodes are the graphite rods dipped in the molten mixture of pure alumina dissolved in molten Cryolite ($Na_3AlF_6$) with some fluorspar ($CaF_2$). Cryolite lowers the melting point of pure alumina up to 950 ° C. When current is passed through the molten alumina the reactions take place:

### Ionization Reaction:

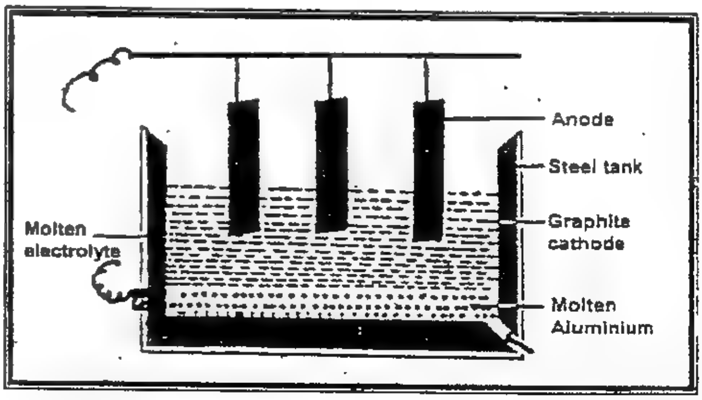
$$2Al_2O_3 \underset{950^\circ C}{\overset{\text{Cryolite}}{\rightleftharpoons}} 4Al^{3+} + 6\,O^{2-}$$

At Cathode: $4Al^{3+} + 12e^- \xrightarrow{950^\circ C} 4Al_{(l)}$

At Anode: $6\,O^{2-} \longrightarrow 3\,O_{2(g)} + 12e^-$

Molten Al metal is produced at cathode which deposited on the bottom of the cell and is tapped off from the outlet of the cell.

Oxygen ($O_2$) gas is liberated at anode which reacts with the carbon anode to form oxides of carbon. As a result the anodes are gradually disappeared and must be replaced from time to time.



# ALLOYS:

**"When a metal is mixed with another metals or non metals in molten form then the mixture is called Alloy."**

The component elements do not undergo any chemical changes during the process of alloying. The percentage composition of the component elements may vary according to the quality desired.

The presence of small quantities of another element in the metal frequently increases its strength and appearance.

## SOME COMMON ALLOYS:

### (1) BRONZE:

This is an alloy of copper (baser metal).

**Composition:** It contains 90 - 95% copper (Cu) and 5 - 10% Tin (Sn).

**Properties:** It is strong and shows greater resistance to corrosion. It is very attractive in appearance.

**Uses:** It is used for making coins, medals, sculptures. It is also used for general metal work.

### (2) BRASS:

This is also an alloy of copper (baser metal).

**Composition:** It contains 60 - 80% copper (Cu) and 20 - 40% Zinc (Zn).

**Properties:** It is stronger and malleable than copper. It has low melting point. It shows greater resistance to corrosion. It is very attractive in appearance. It is low cost than copper.

**Uses:** It is used for making moving parts of clocks, watches and doors. It is also used for making ornaments, household utensils.

### (3) NICHROME:

This is an alloy of Nickel (baser metal).

**Composition:** It contains 60% Nickel (Ni), 25% Iron (Fe) and 15% Chromium (Cr).

**Properties:** It is heat resistant.

**Uses:** It is used for making wires for electric iron and heater.



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# EXERCISE:

**(1) Fill in the blanks by the correct answer.**

(i) Aluminium is the member of group ***IIIA*** of the periodic table.

(ii) During the extraction of *Al*, bauxite is purified by dissolving it in ***NaOH*** solution, the insoluble impurities are removed by ***Filtration.***

(iii) Elements in the periodic table are classified mainly as ***metals*** and ***non-metals.***

(iv) Metals are good conductor of heat and electricity.

(v) Metals have greater tendency to ***lose*** electrons and generally are ***reducing*** agents.

(vi) The combined forms of metals with less definite chemical impurities are known as ***minerals***, with less worth impurities are called ***gangue.***

(vii) The formula of haematite is $\underline{Fe_2O_3}$.

(viii) $Na_3AlF_6$ is the formula of ***Cryolite.***

(ix) $CaO + SiO_2 \longrightarrow \underline{CaSiO_3}$

(x) Bronze contains 90-95% copper and ***5-10%*** tin.

**(2) Write True of False for the following statements.**

(i) Blister copper is refined by electrolytic process. **[True]**

(ii) Ore is the pure form of a metal oxide. **[False]**

(iii) The chief ore of iron is magnetite. **[False]**

(iv) Pig iron is hard and brittle. **[True]**

(v) Brass is silvery white colour. **[False]**

(vi) $CaSiO_3$ and $FeSiO_3$ are known as slag. **[True]**

(vii) Metals are usually soft and brittle. **[False]**

(viii) Non-metals can not be polished like metals. **[True]**

(ix) An ore can be concentrated also by magnetic separator. **[False]**

(x) Impurities of Au, Ag & Zn are removed from blister copper by roasting. **[False]**

**(3) Tick the correct answer.**

(i) The formula of iron rust is:

(a) $Fe_2O_3$  (b) $Fe_3O_4$
√ (c) ***$Fe_2O_3 . H_2O$***  (d) FeO

(ii) The most important ore of copper is:

(a) $Cu_2O$  √ (b) ***$CuFeS_2$***
(c) $Cu_2S$  (d) $Cu\,cO_3 . Cu(OH)_2$

(iii) The formula of potash mica is:

√ (a) ***$K_2O . 3Al_2O_3 . 6SiO_2 . 2H_2O$***  (b) $Al_2O_3 . 2SiO_2 . 2H_2O$
(c) $K_2O . Al_2O_3 . 6SiO_2$  (d) $Al_2O_3$

(iv) Chromite is found in Pakistan at:

(a) Azad kashmir  (b) Punjab
(c) Sindh  √ (d) ***Baluchistan***

(v) Iron metal obtained from blast furnace is impure and is called:

(a) Cast iron  √ (b) ***Pig iron***
(c) Steel  (d) Wrought iron

(vi) Stainless steel is an alloy of iron with:

(a) Cr and Mn  √ (b) ***Ni and Cr***
(c) Mn and S  (d) C and S

(vii) Which one is the reduction reaction in the manufacture of blister copper?

(a) $2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_{2(g)}$

(b) $FeO + SiO_2 \longrightarrow FeSiO_3$

(c) $2Cu_2S + Cu_2S \longrightarrow 6Cu + SO_{2(g)}$

√ (d) ***$2CuO + Cu_2S \longrightarrow 6Cu + SO_2$***

(viii) The chief ore of $Al$ has the formula:

√ (a) $Al_2O_3 . 2H_2O$ (b) $Al_2O_3$

(c) $Al_2O_3.H_2O$ (d) $Na_3AlF_6$

(ix) Nichrome is an alloy that contains major percentage of:

(a) Cr (b) Fe

√ (c) *Ni* (d) Zn

(x) The medal given at third position in any event is made up of:

(c) Nichrome (d) Copper

(4) (a) Define the following terms.

(i) Minerals (ii) Ores (iii) Metallurgy

(b) Write down the preliminary operations or preparations involved in the metallurgy of metals from their ores. Discuss only concentration of the ore and the roasting of the concentrated ores.

(c) What happens when metals Zn, Mg and $Al$ react with dilute $HCl$ and $H_2SO_4$? Give reactions.

(d) Give the reactions of the followings with water.

(i) $PCl_3$ (ii) $CaH_2$ (iii) $NH_3$

(5) (a) What are the chief ores of Iron? How is iron obtained by the blast furnace?

(b) What are the main components of pig iron?

(c) Differentiate between wrought iron and steel.

(6) (a) What is rusting? How is rusting controlled?

(b) Before the extraction of a metal begins, ores must be purified and concentrated. Mention two different processes by which it is done.

(c) Why does in metal extraction often slag is produced?

(7) (a) What are the different ores of copper? Name some of the chief ore of copper from which copper is extracted.

(b) How copper ore is concentrated by Froth Floatation process?

(c) Discuss various steps involved in obtaining blister copper.

(d) How is blister copper further purified? Write down the process of purification of blister copper.

(8) (a) What are different ores of Aluminium? What is the percentage of aluminium compounds present in the earth crust?

(b) Describe the extraction of Aluminium metals from its bauxite ore? Give details including purification and electrolysis of pure alumina..

(c) Write down the formula of the followings:

(i) Lime stone (ii) Iron silicate (iii) Alumina

(iv) Iron pyrite (v) Copper pyrite (vi) Chromite

(9) (a) What do you mean by alloy? Describe the composition and applications of important alloys of copper.

(b) What is nichrome?

(c) Give the physical characteristics of copper metal.

(d) What are three common stainless steel and their compositions?

SESSION 2016-2017

# CLASS-IX

# CHEMISTRY

## Chapter # 17

## ORGANIC CHEMISTRY


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# ORGANIC CHEMISTRY 17

## INTRODUCTION:

Early chemists considered the substances according to their sources like **organic** from living things and **inorganic** from non living things. This classification was based on source but not on composition.

## FORMER CONCEPT (VITAL FORCE THEORY):

· **Berzellius** believed that organic compounds are derived by **Vital Force** which means they obtained from living things or life.

## MODERN CONCEPT:

In 1828, **Wohler** prepared an organic compound *Urea* (a compound in animal urine) from inorganic compound Ammonium Cyanate ($NH_4CNO$) in the laboratory by control heating.

$$NH_4CNO \longrightarrow NH_2-\overset{\overset{\displaystyle O}{\|}}{C}-NH_2 \quad \textit{(Urea)}$$

***"The compounds which contain carbon are called organic compounds."***

The branch of chemistry which deals with the study of carbon compounds is called organic chemistry.

Except few compounds such as carbon dioxide ($CO_2$), carbon monoxide (CO), metal carbonates ($CO_3$) metal bicarbonate ($HCO_3$) and metal cyanide (CN) which are considered as inorganic compounds.

## SPECIFIC PROPERTIES OF ORGANIC COMPOUNDS:

Following are the some specific properties of organic compounds:

| | |
|---|---|
| (i) Combustion | (ii) Cracking (Pyrolysis) |
| (iii) Isomerism | (iv) Polymerism |
| (v) Functional group | (vi) Homologous series |

## (i) COMBUSTION:

*When organic compounds burn in presence of air (oxygen) then carbon dioxide gas and water vapours are formed while large amount of heat is liberated. This process is called combustion.*

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{heat}$$

$$C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O + \text{heat}$$

## (ii) CRACKING (PYROLYSIS):

When saturated organic comounds are heated in absence of air then they break in different components. This process is called cracking or pyrolysis.

Scientifically,

***The alkanes of large molecular mass are heated in absence of air then the molecules split into several smaller components.***

**e.g.**

At 700-800°C, propane ($C_3H_8$) is heated in absence of air (oxygen) then it cracks into propene, ethene, methane and hydrogen.

$$\underset{\text{Propane}}{2(CH_3\text{-}CH_2\text{-}CH_3)} \xrightarrow[\text{Absence of air}]{700\text{-}800^\circ C} \underset{\text{Propene}}{CH_3-CH=CH_2} + \underset{\text{Ethene}}{CH_2=CH_2} + \underset{\text{Methane}}{CH_4} + H_2$$

## (iii) ISOMERISM:

***The different compounds have same molecular formula but their structures are different are called isomers (same parts) and this phenomenon is known as isomerisation or isomerism.***

In Greek **Iso** means **same** and **meros** means **parts** or **units**. The isomers have same percentage composition of elements and molecular mass.

**e.g**

Normal butane (n-butane) and iso-butane have the same molecular formula ($C_4H_{10}$) but their structures are different, so they show different physical properties.

$$\underset{\text{n-butane }(C_4H_{10})}{CH_3-CH_2-CH_2-CH_3} \qquad \underset{\text{Iso-butane }(C_4H_{10})}{CH_3-\underset{\underset{CH_3}{|}}{CH}-CH_3}$$

**n-butane and iso-butane are isomers**

Normal pentane (n-pentane), iso-pentane and neo-pentane have the same molecular formula ($C_5H_{12}$) but their structures are different, so they show different physical properties.

$$\underset{\text{n-pentane }(C_5H_{12})}{CH_3-CH_2-CH_2-CH_2-CH_3} \qquad \underset{\text{iso-pentane }(C_5H_{12})}{CH_3-CH_2-\overset{\overset{CH_3}{|}}{CH}-CH_3} \qquad \underset{\text{neo-pentane }(C_5H_{12})}{CH_3-\underset{\underset{CH_3}{|}}{\overset{\overset{CH_3}{|}}{C}}-CH_3}$$

**n-pentane, iso-pentane and neo pentane are isomers**

This type of isomerism is called chain or skeletal isomerism, and this type of isomerism always occurs among the alkanes.

The prefix n-is normal for unbranched chain where as prefix iso-is for two methyl groups ($-CH_3$) on any corner of the basic chain and prefix neo-is for three methyl groups ($-CH_3$) on any corner of the basic chain.

## (iv) POLYMERISM (POLYMERISATION):

*When unsaturated organic compounds are heated in absence of air or presence of limited air, then they linked (joined) together to form a new compound which is called polymer and this process is called polymerism.*

The linkage of monomers to form a Polymer.

In Greek **Poly** means **many** and **meros** means **parts** or **units** so the linkage of many molecules (monomers) forms a compound (Polymer).

### Formation of Polyethene (Polyethylene):

In presence of a suitable catalyst ethene (ethylene) is heated then polyethene is formed.

$$n(CH_2=CH_2) \xrightarrow{0.01\%\text{oxygen}} \underset{\text{Polyethene}}{(-CH_2-CH_2-)n}$$

*Polyethene or polyethylene is also known as Polythene.*

## (v) FUNCTIONAL GROUP:

An atom or group of atoms present in a molecule which gives the unique character and the properties to the molecule is called **Functional Group**.

| Compound | General Formula | Functional Group | Example | Name |
|---|---|---|---|---|
| Organic acids | $R-\overset{\overset{O}{\Vert}}{C}-OH$ | $-\overset{\overset{O}{\Vert}}{C}-OH$ (Carboxyl group) | $CH_3-\overset{\overset{O}{\Vert}}{C}-OH$ | Acetic acid |
| Alcohols | R-OH | –OH (Hydroxyl group) | $CH_3-OH$ | Methyl alcohol |
| Alkyl halides | R-X | –X (Halide group) | $CH_3-Cl$ | Methyl chloride |

## (vi) HOMOLOGOUS SERIES

*A series of different organic compounds have same General Formula and each member has a difference of >$CH_2$ (methylene group) is said to be homologous series.*

In Greek, **Homo** means **same** and **logous** means **ratio**. Organic compounds can be classified into series (families) whose members are closely related in molecular structure and properties.

**e.g.**

The alkanes, alcohols and alkyl halides listed in the table below, show the difference of methylene group:

| No. of carbon | Alkanes (R-H) | Alcohols (R - OH) | Alkyl halides (R-X) |
|---|---|---|---|
| 01 | Methane ($CH_4$) | Methyl alcohol ($CH_3$-OH) | Methyl chloride ($CH_3$-Cl) |
| 02 | Ethane ($C_2H_6$) | Ethyl alcohol ($C_2H_5$-OH) | Ethyl chloride ($C_2H_5$-Cl) |
| 03 | Propane ($C_3H_8$) | Propyl alcohol ($C_3H_7$-OH) | Propyl chloride ($C_3H_7$-Cl) |
| 04 | Butane ($C_4H_{10}$) | Butyl alcohol ($C_4H_9$-OH) | Butyl chloride ($C_4H_9$-Cl) |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |
| n | $C_nH_{2n+2}$ | $C_nH_{2n+1}OH$ | $C_nH_{2n+1}X$ |

## HYDROCARBONS

***Organic compounds containing Hydrogen (H) along with Carbon (C) are known as hydrocarbons.***

**Hydrocarbons**

(a)Aliphatic Hydrocarbons — (b)Alicyclic Hydrocarbons — (c)Aromatic Hydrocarbons

## (a) ALIPHATIC HYDROCARBONS

Aliphatic Hydrocarbons are composed of **open chains** of carbon atoms: they are further classified into two classes:

### (i) Saturated Hydrocarbons:

Saturated hydrocarbons contain only **single bonds** between the carbon atoms; it means the valency of carbon is fully utilized. **Alkanes** are the example of saturated hydrocarbons e.g. $CH_4$, $C_2H_6$, $C_3H_8$, etc.

### (ii) Unsaturated Hydrocarbons:

Unsaturated hydrocarbons contain **one or more double or triple bonds**. It means that the valency of carbon is not fully utilized.

Those which contain double bond are called **alkenes** and which contain triple bond are called **alkynes**.

The common examples of Alkenes and Alkynes are:

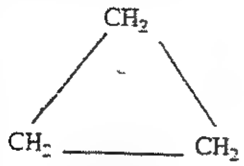
$C_2H_4$ ($CH_2 = CH_2$)
Ethylene
(Ethene)

$C_2H_2$ ($HC \equiv CH$)
Acetylene
(Ethyne)

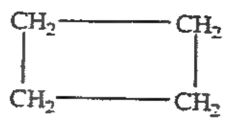
## (b) ALICYCLIC COMPOUNDS:

Alicyclic hydrocarbons are the compound in which carbon atoms are arranged in rings.

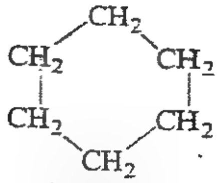
The cyclo alkanes have two fewer hydrogen atoms than alkanes. They have the General formula ($C_nH_{2n}$). e.g.



Cylopropane



Cyclobutane

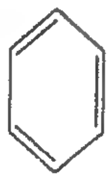


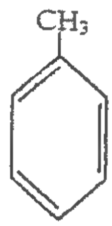
Cyclohexane

## (c) AROMATIC COMPOUNDS:

Aromatic hydrocarbons contain six carbon member in rings with **alternate single and double bond.**

Aromatic hydrocarbons contain Benzene ring and the compounds those derived from benzene.


$C_6H_6$
Benzene



$C_6H_5-CH_3$
Toluene

**Aliphatic Hydrocarbons**

- Saturated Hydrocarbons
  - Alkanes
  - Paraffins
  - $-\overset{|}{\underset{|}{C}}-\overset{|}{\underset{|}{C}}-$
  - General Formula $C_nH_{2n-2}$
- Unsaturated Hydrocarbons
  - Alkenes → Olefins → $>C=C<$ → $C_nH_{2n}$
  - Alkynes → Acetylenes → $-C\equiv C-$ → $C_nH_{2n-2}$

# ALKANES, ALKENES AND ALKYNES:

## 1. Alkanes:

Alkanes are saturated hydrocarbons in which various carbon atoms are linked by **single covalent bonds** to adjacent carbon atoms forming chains.

Alkanes have a general formula ($C_nH_{2n-2}$) which show that all the valenices of carbon are fully satisfied; hence all alkanes are unreactive. For this reason they are called **paraffins** (from the Latin **Para** means **little** and **affins** means **attraction**).

## 2. Alkenes:

Alkenes are unsaturated hydrocarbons in which **one double bond** is present between two carbon atoms.

Alkenes contain two less hydrogen atoms than the corresponding alkanes. Alkenes have a general formula ($C_nH_{2n}$).

The first member of **alkenes** is **ethylene** or **ethene**, hence alkenes are known as **olefins** (oil making).

## 3. Alkynes:

Alkynes are unsaturated hydrocarbons in which **one triple bond** is present between two carbon atoms.

Alkynes contain four less hydrogen atoms than the corresponding alkanes. Alkynes have a general formula, ($C_nH_{2n-2}$).

The first member of **alkynes** is **acetylene** or **ethyne**, hence alkynes are known as acetylene series.

# NAME OF FIRST TEN HYDROCARBONS: (ALKANES, ALKENES and ALKYNES):

The names of first ten hydrocarbons are in the following chart. The ending for all of the name of alkanes is **ane**, alkenes is **ene** and alkynes is **yne**.

The first four members retain their original names.

Thus **one**, **two**, **three**, **four**, **five** becomes **meth**, **eth**, **prop**, **but**, **pent**, etc.

| No. of carbon | Molecular formula of Alkane | Name of Alkane | Molecular formula of Alkene | Name of Alkene | Molecular formula of Alkyne | Name of Alkyne |
|---|---|---|---|---|---|---|
| Meth- (1) | $CH_4$ | methane | --------- | --------- | --------- | --------- |
| Eth- (2) | $C_2H_6$ | ethane | $C_2H_4$ | ethene | $C_2H_2$ | ethyne |
| Prop- (3) | $C_3H_8$ | propane | $C_3H_6$ | propene | $C_3H_4$ | propyne |
| But- (4) | $C_4H_{10}$ | butane | $C_4H_8$ | butene | $C_4H_6$ | butyne |
| Pent- (5) | $C_5H_{12}$ | pentane | $C_5H_{10}$ | pentene | $C_5H_8$ | pentyne |
| Hex- (6) | $C_6H_{14}$ | hexane | $C_6H_{12}$ | hexene | $C_6H_{10}$ | hexyne |
| Hept- (7) | $C_7H_{16}$ | heptane | $C_7H_{14}$ | heptene | $C_7H_{12}$ | heptyne |
| Oct- (8) | $C_8H_{18}$ | octane | $C_8H_{16}$ | octene | $C_8H_{14}$ | octyne |
| Non- (9) | $C_9H_{20}$ | nonane | $C_9H_{18}$ | nonene | $C_9H_{16}$ | nonyne |
| Dec- (10) | $C_{10}H_{22}$ | decane | $C_{10}H_{20}$ | decene | $C_{10}H_{18}$ | decyne |

# CHEMISTRY OF METHANE ($CH_4$):

## INTRODUCTION:

Methane is the first member of alkane with a molecular formula $CH_4$. Methane is an end product of decay of plants and is found at **marshy** places so is called **Marsh Gas** $CH_4$ is a major component (94%) of natural gas. It is largely found in Sui at Baluchistan in Pakistan and known as Sui gas.

In coal mines, mixture of methane ($CH_4$) and air forms a dangerous **fire damp** (German: damp = vapours) which explodes on contact with flame. Hence it is also called **Fire-Damp**.

## PREPARATION:

In laboratory methane is prepared by the following two methods:

(i) From Sodium acetate ($CH_3$–COONa).

(ii) By hydrolysis of aluminium carbide ($Al_4C_3$).

### (i) FROM SODIUM ACETATE ($CH_3$–COONa)

When anhydrous sodium acetate is heated with soda lime (NaOH + CaO) then methane gas is formed.

$$CH_3-COONa_{(aq)} + NaOH_{(aq)} \xrightarrow[heat]{CaO} CH_{4(g)} + Na_2CO_{3(aq)}$$

### (ii) BY HYDROLYSIS OF ALUMINIUM CARBIDE ($Al_4C_3$).

When aluminum carbide reacts with water then methane gas is formed and large amount of heat is produced.

$$\underset{\text{Aluminium carbide}}{Al_4C_3} + 12H_2O \longrightarrow 3CH_{4(g)} + \underset{\text{Aluminium hydroxide}}{4Al(OH)_{3(aq)}}$$

## PHYSICAL PROPERTIES:

(1) Methane is colourless, tasteless and odourless gas.

(2) It is lighter than air and burns with blue flame.

(3) It is sparingly soluble in water (5ml in 100ml).

(4) Methane is non polar so it is dissolved in organic solvents.

## CHEMICAL PROPERTIES:

Methane does not react with aqueous solution of acids, alkali, $KMnO_4$ or other oxidizing agents because of non-polar and saturated character.

In methane, all the four valencies of carbon are fully (utilized) satisfied. It is saturated and **can not give addition reaction** but it forms a derivative only by **substitution reaction**. Its important substitution reaction is **halogenation**.

### (i) HALOGENATION:

The reaction in which one or more atoms are replaced by other atoms is known as **substitution reaction**. If the substitution occurs by halogens the reaction is known as halogenation.

Methane may be chlorinated or brominated by treatment with $Cl_2$ or $Br_2$ in the presence of sun light (S.L) or ultra violet light (U.V.L).

If the mixture of methane and $Cl_2$ is exposed to (S.L) or (U.V.L), reaction occurs with the progeressive replacement of the hydrogen atoms by (Cl) atoms and the mixture of the following four products is obtained.

$$Cl_2 \xrightarrow[U.V.L]{S.L} 2Cl^{\circ}$$

$$CH_4 + Cl_2 \xrightarrow[U.V.L]{S.L} \underset{\text{Methyl chloride (Chloromethane)}}{CH_3-Cl} + HCl$$

$$CH_3+Cl + Cl_2 \xrightarrow{S.L} \underset{\text{Methylene chloride (Dichloromethane)}}{CH_2+Cl_2} + HCl$$

$$CH_2+Cl_2 + Cl_2 \xrightarrow{S.L} \underset{\text{Chloroform (Trichloromethane)}}{CHCl_3} + HCl$$

$$CH+Cl_3 + Cl_2 \xrightarrow{S.L} \underset{\text{Carbon tetra chloride (TetraChloromethane)}}{CCl_4} + HCl$$



## (ii) COMBUSTION or OXIDATION:

Methane on complete oxidation or combustion gives $CO_2$, water and heat. Due to this reason $CH_4$ is an important industrial and domestic fuel.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O \;; \qquad \Delta H = -890 KJ/mol.$$

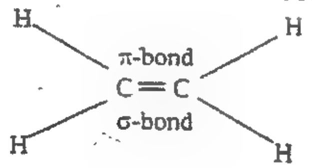
## USES OF METHANE:

(1) Methane is used as an important industrial and domestic fuel.
(2) It is used in the preparation of $CH_3OH$, $CHCl_3$, $CCl_4$ and pure carbon.
(3) It is also used to produce $H_2$ for the production of fertilizers and ammonia.

## CHEMISTRY OF ETHENE (ETHYLENE) $CH_2=CH_2$:

## INTRODUCTION:

The first member of alkene series is ethene. It is also called ethylene. It is unsaturated because it contains one double bond between two carbon atoms.




It is produced commercially by cracking of petroleum so it is also called Petro-Chemical.

## PREPARATION:

### By Dehydration of Ethyl Alcohol:

Ethene is prepared by dehydration of ethyl alcohol (ethanol). Ethyl alcohol on dehydration (removal of water molecule) gives ethene. Dehydration of ethyl alcohol can carried out in the presence of dehydrating agents such as $H_2SO_4$ or $Al_2O_3$ at high temperature.

(i) $CH_3-CH_2-OH + H_2SO_4 \xrightarrow[H_2SO_4]{160^{\circ}C-180^{\circ}C} H_2C=CH_2 + H_2O$

(ii) $CH_3-CH_2-OH + Al_2O_3 \xrightarrow[Al_2O_3]{300^{\circ}C-350^{\circ}C} CH_2=CH_2 + H_2O$

## PHYSICAL PROPERTIES:

(1) Ethene (Ethylene) is colourless gas having pleasant smell.
(2) It is slightly lighter than air and burns with luminous flame.
(3) It is slightly soluble in water but it is soluble in organic solvents.

## CHEMICAL PROPERTIES:

Ethene gives addition reaction due to the presence of double bond. In ethane, strong sigma ($\sigma$) bonds are present but in **ethene** ($\pi$) electrons are present which holds carbon more loosely and seek to form strong sigma bonds with other atoms.

Ethylene gives addition reaction due to presence of one ($\pi$) bond.

## (i) ADDITION REACTIONS:

The most important addition reactions of ethene are:

(1) Addition of Hydrogen ($H_2$) (2) Addition of Halogen ($X_2$)

(3) Addition of Halogen acid (HX)

### 1. HYDROGENATION or REDUCTION [ADDITION of $H_2$]:

In presence of catalyst (Ni, Pt or Pd) ethene reacts with $H_2$ then ethane is formed.

$$CH_2=CH_2+H_2 \xrightarrow[300°C]{Ni} CH_3-CH_3$$

Such reactions are called catalytic reductions or hydrogenations.

### 2. HALOGENATION [ADDITION of $X_2$ ($Cl_2$, $Br_2$)]:

Ethene reacts with bromine molecule ($Br_2$) to from ethylene dibromide or 1, 2 dibromoethane.

$$CH_2=CH_2+Br_2 \longrightarrow \underset{\text{1, 2-dibromoethane (Vicinal dibromide)}}{Br-CH_2-CH_2-Br}$$

In this test the colour of bromine solution is discharged which means ethene is unsaturated hydrocarbon.

### 3. HYDRO-HALOGENATION [ADDITION of HX (HCl, HBr)]:

Ethene reacts with halogen acid which gives ethyl halide.

When ethene reacts with hydrobromic acid (HBr) then ethyl bromide is formed.

$$CH_2=CH_2+H-Br \longrightarrow CH_3-CH_2-Br$$

## (ii) COMBUSTION:

Ethene on complete combustion gives $CO_2$, water and heat.

$$CH_2=CH_2+3O_2 \longrightarrow 2CO_2+2H_2O+\text{Heat}$$

## (iii) POLYMERIZATION OR FORMATION OF POLYETHENE:

In presence of a suitable catalyst, ethene (ethylene) is heated then polyethene is formed.

$$n(CH_2=CH_2) \xrightarrow{0.01\%\ \text{oxygen}} \underset{\text{Polyethene}}{(-CH_2-CH_2-)n}$$

***Polyethene or polyethylene is also known as Polythene.***

## USES OF ETHENE (ETHYLENE):

(1) It is used for ripening the fruits.

(2) It is used for manufacture of polyethene plastic.

(3) Its mixture with oxygen is used as an excellent general anesthesia.

(4) It is used for manufacture of alcohol, ethylene glycol and ethyl chloride.

# CHEMISTRY OF ETHYNE (ACETYLENE) $HC \equiv CH$:

## INTRODUCTION:

The first member of alkyne series is ethyne. It is also called acetylene. It is more unsaturated than ethene because it contains one triple bond between two carbon atoms.

$$H-C\equiv C-H$$

It is found in natural gas and petroleum.

## PREPARATION:

**By Hydrolysis of Calcium Carbide:**

Ethyne is prepared by the action of water on calcium carbide ($CaC_2$).

$$CaC_2 + 2(H-OH) \longrightarrow \underset{\text{Ethyne}}{C_2H_2} + Ca(OH)_{2(aq)}$$

## PHYSICAL PROPERTIES:

(1) Acetylene is colourless gas with garlic odour.

(2) It is slightly soluble in water but it is soluble in organic solvents.

(3) Liquid acetylene explodes violently by shock or heat.

## CHEMICAL PROPERTIES:

Ethyne gives addition reaction due to the presence of triple bond. In ethane, strong sigma ($\sigma$) bonds are present but in **ethyne** ($\pi$) electrons are present which holds carbon more loosely and seek to form strong sigma bonds with other atoms. Acetylene gives addition reaction due to presence of two ($\pi$) bonds.

## (i) ADDITION REACTIONS:

The most important addition reactions of ethyne are:

(1) Addition of Hydrogen ($H_2$) (2) Addition of Halogen ($X_2$)

(3) Addition of Halogen acid (HX)

### 1. HYDROGENATION or REDUCTION [ADDITION of $H_2$]:

In presence of catalyst (Ni, Pt or Pd), ethyne reacts with $H_2$ to give ethene and then ethane.

$$HC\equiv CH + H_2 \xrightarrow[200^\circ C]{Ni} \underset{\text{Ethene}}{CH_2 = CH_2} - H_2 \xrightarrow[300^\circ C]{Ni} \underset{\text{Ethane}}{CH_3 - CH_3}$$

### 2. HALOGENATION [ADDITION of $X_2$ ($Cl_2$, $Br_2$)]:

Ethyne reacts with $Br_2$ and $Cl_2$ to give acetylene dibromide or dichloride and then acetylene tetrabromide or tetrachloride.

$$HC\equiv CH + Br_2 \longrightarrow Br-HC=CH-Br + Br_2 \longrightarrow \begin{array}{c} Br\quad Br \\ |\qquad | \\ H-C-C-H \\ |\qquad | \\ Br\quad Br \end{array}$$

## 3. HYDRO-HALOGENATION [ADDITION of HX (HCl, HBr)]:

Acetylene adds two molecules of H-Br and first forms vinyl bromide and then ethylene dibromide.

$$HC\equiv CH + H-Br \longrightarrow \underset{\text{Vinyl bromide}}{H_2C=CH-Br} + \overset{\delta+\ \delta-}{H-Br} \longrightarrow \underset{\text{Ethylene di bromide}}{H_3C-CH\begin{matrix}Br\\Br\end{matrix}}$$

## (ii) COMBUSTION:

Ethyne on complete combustion gives $CO_2$, water and heat.

$$2(CH\equiv CH) + 5O_2 \longrightarrow 4CO_2 + 2H_2O + \text{heat}$$

When acetylene is burnt in presence of pure oxygen then very hot flame is produced. This flame is enough hot and a temperature of 3000°C is reached. So it is used for cutting and welding of metals.

## (iii) OXIDATION:

Acetylene is oxidized to formic acid in presence of aqueous $KMnO_4$ solution, as well as with hot alkaline $KMnO_4$, gives oxalic acid.

(i) $CH\equiv CH + H_2O + 3[O] \xrightarrow[\text{cold}]{KMnO_4} 2H\text{-}COOH$ (formic acid)

(ii) $HC\equiv CH + 4[O] \xrightarrow[\text{hot}]{KMnO_4} HO-\overset{\overset{O}{\|}}{C}-\overset{\overset{O}{\|}}{C}-OH$ (oxalic acid)

## USES OF ACETYLENE:

(1) It is used in welding and cutting iron and steel.

(2) It is used for manufacture of plastic, rubber, P.V.C pipes.

(3) It is also used to prepare acetaldehyde, acetic acid, ethanol, etc.

## NATURAL SOURCES OF ORGANIC COMPOUND

The basic source of organic compounds is living organisms i.e. Animals, Plants, Coal, Natural gas and Petroleum. They are described as under:

## (1) ANIMAL AND PLANT KINGDOM:

Animals produce fats, proteins, urea, uric acid, vitamins, etc. Plants provide carbohydrates (sugar, starch, cellulose), citric acid, oxalic acid, oils and vitamins.

## (2) COAL:

Coal is a complex material. It is composed of mainly carbon, but it also contains small percentage of other elements. The coal gives peat, lignite and high grade anthracite. When coal is heated in absence of air in an oven it undergoes destructive distillation into three main products.

Coal

↓ Coal gas or oven gas | ↓ Coke | ↓ Coal tar

(i) Coal gas or oven gas mainly contains hydrogen, methane and $CO_2$ gas.

(ii) Coke is pure carbon and is used in metallurgy of iron and steel and for the manufacture of the calcium carbide.

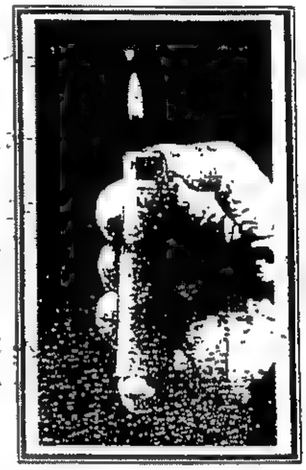
(iii) Coaltar a black viscous liquid gives aromatic hydrocarbon.

The fractional distillation of Coaltar gives so many hydrocarbons.

**e.g.**

- Coaltar on fractional distillation upto 170°C gives light oil (**Naptha**) which mainly gives benzene, toluene, xylenes, etc. Over 215 aromatic hydrocarbons are isolated from Coaltar.

## (3) NATURAL GAS:



Natural gas is found wherever oil and coal ($CH_4$) along with small quantities of ethane, propane, butane and also contains carbon dioxide, nitrogen and occasionally helium (He).

Natural gas is better industrial and domestic fuel than coal gas.

Natural gas is piped from gas wells for use as fuel in homes. industries and into thermal electric power stations. Certain components such as propane and butane may be separated from the gas at the wells. Bottled in tanks under pressure and sold as bottled gas also called liquefied petroleum gas (LPG) where natural gas lines are not available.

In Pakistan, it is largely found at Sui in Baluchistan, called Sui-gas. Also Sindh at various places like, Khairpur, Mari (Mari gas) in Badin. It is also found in Punjab at Dhodak and Radho, district Dera Ghazi Khan.

## (4) PETROLEUM

The most abundant and important of all natural sources of organic compounds is petroleum which mean (Petra = Rock + Oleum = Oil) i.e. Rock oil. The dark viscous liquid found in underground deposits in various parts of earth at different depths. Petroleum is extremely complex mixture of gaseous, liquid and solid hydrocarbons ranging from ($C_1$ – $C_{40}$), together with the varying amounts of compounds containing oxygen, sulphur and nitrogen.

In petroleum, there are two types of hydrocarbons i.e. paraffins and cyclo paraffins (cyclohexane, $C_6H_{12}$). It is generally believed that it has been formed by remains of plants and animals which lived in the warm inland and oceans million of years ago. The chemical effects of pressure, temperature and bacteria have converted these remains into petroleum.

In Pakistan, the important Petroleum reserves are in Meyal in Pothohar areas of Punjab and some places in District Badin, Dadu and Hyderabad in Sindh.

## FRACTIONAL DISTILLATION OF PETROLEUM (REFINING OF PETROLEUM):

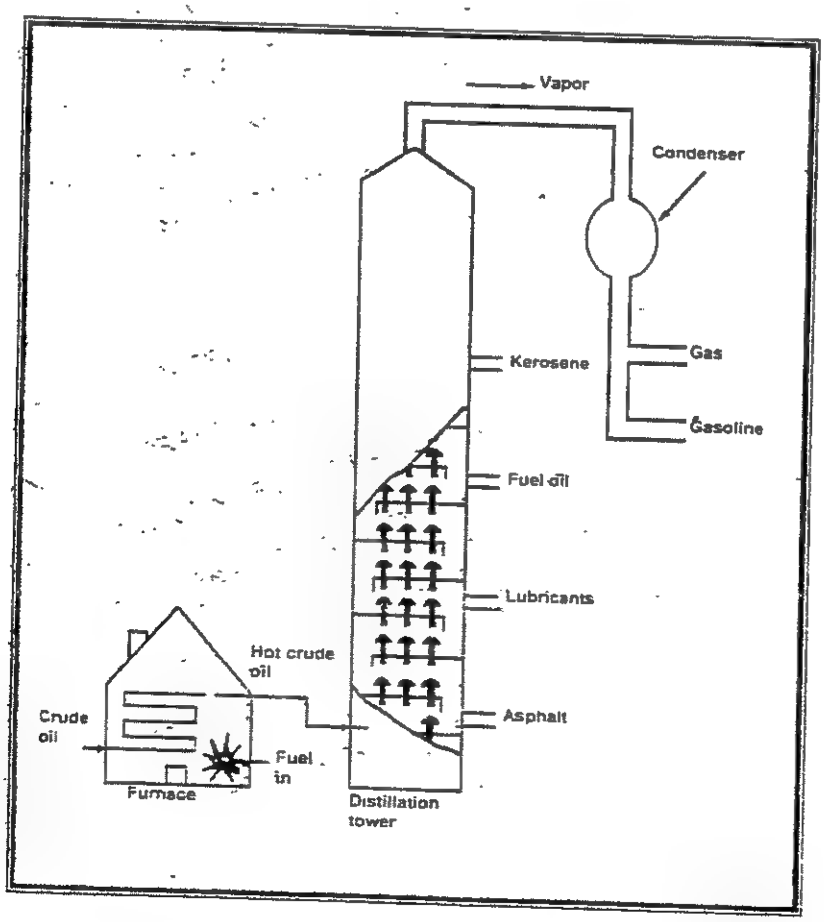
In this process, the petroleum or crude oil is heated above 400°C to vapourize. The resulting vapours are then carried to a fractionating column having different temperature zones i.e. fractionating column is divided into several compartments; each compartment has a specific range of temperature.

More than five hundred hydrocarbons are separated from petroleum.

The lighter molecules come off at top of the distillation column and the heavier at the bottom. Before the development of automobile, the most important product from petroleum was kerosene oil. It was used for lighting.

Now gasoline is the most important product with diesel fuel, heavy oils and various lubricants.

Petroleum is becoming increasingly important as a source of energy and for the preparations of hundreds of diverse organic compounds. One of the main operation in refining is to separate the petroleum into useful fraction.

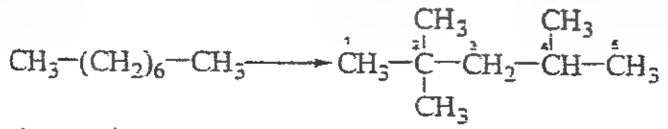


| Boiling range | Range of carbon atoms per molecule | Name of the fractions | Uses |
|---|---|---|---|
| Below 20°C | $C_1$-$C_4$ | Petroleum gases mixture of methane, ethane, propane and butane. | Fuels for homes and industries for heating and cooking. In the manufacture of petrochemicals. |
| 20°C-60°C<br>60°C-120°C | $C_5$-$C_6$<br>$C_6$-$C_7$ | Petroleum Ether (liquid). Light naptha (ligroin); liquids. | Both the products are used as organic solvents for cleaning textile fabrics. |
| 40°C-200°C | $C_6$-$C_{10}$ | Gasoline or Petrol. | Fuel for automobile engines |
| 175°C-325°C | $C_{11}$-$C_{16}$ | Kerosene. | As a fuel in domestic stoves, jet engines, as a solvent for grease and paints. |
| 250°C-400°C | $C_{14}$-$C_{25}$ | Diesel oil or Gas oil. | As a fuel for diesel engines, for heating purposes and as a raw material for cracking. |
| Above 400°C | $C_{20}$-$C_{higher}$ | Lubricating or heavy oils Non-volatile liquid. | For lubrication as grease in moving parts of engines and machines. |
| Obtained by vacuum distillation of the remaining fractions. | $C_{20}$-$C_{40}$ | Paraffin wax i.e. nonvolatile solids. | Packing material, making of candles, water proof materials, polish, Vaseline. |
| Solid residue left behind | Solid carbon | Bitumen (pitch) asphalt. | For surfacing roads and airfields, roofing material, in protective paint and pipe coatings etc. |

## REFORMING OF PETROLEUM:

Petrol or gasoline is a mixture of hydrocarbons generally consisting of six to ten carbon atoms per molecule. It is a volatile liquid which is a common fuel. Gasoline is reformed to prevent fuel knock in the motor engine. Knocking is caused by the rapid and uneven burning of straight chain hydrocarbons and generally leads to loss of power or damage to the engine. Reforming is a process similar to the process of cracking by which octane-rating i.e octane number of gasoline can be increased.

The quality of petrol is measured in terms of its **octane-rating.** By the process of reforming the straight chain hydrocarbons are converted into branched chain hydrocarbons. Knock inhibitor like TEL {Tetra Ethyl Lead} [Pb $(C_2H_5)_4$] is also added but Lead being poisonous produce environmental pollution. So petrol is heated in the presence of silicate catalyst to convert straight chain hydrocarbons into branched chain hydrocarbons. For example, when n-octane is heated in the presence of silicate catalyst, it is converted into 2, 2, 4-trimethyl pentane, thus producing the higher grade gasoline.



(n-octane) 2, 2, 4 trimethyl pentane

# EXERCISE

**Tick the Correct Answer:**

1. The branch of chemistry which deals with the compounds of carbon, is called:
   (a) Physical chemistry (b) Inorganic chemistry
   √(c) *Organic chemistry* (d) Analytical chemistry
2. The first synthetic organic compound is:
   (a) Methane (b) Ethane
   √(c) *Urea* (d) Acetic acid
3. Which is pure carbon?
   (a) Coaltar (b) Coal gas
   √(c) *Coke* (d) None of these
4. Residue left after fractional distillation of Coaltar:
   (a) Coke (b) Matte
   √(c) **Pitch** (d) None of these
5. Natural gas mainly consists of:
   √(a) *Methane* (b) Ethane
   (c) Propane (d) Butane
6. Fraction of petroleum containing 10-13 carbons, and its boiling range 150°C-230°C:
   (a) Natural gas (b) Gasoline
   √(c) *Kerosene* (d) Light oil
7. Fraction of petroleum containing $C_{21} - C_{40}$ and boiling range is above 400°C, is:
   (a) Light oil (b) Heavy oil
   √(c) *Praffin wax* (d) Bitumen
8. The oils that have been carefully purified and decolourized, act as mild laxative are:
   √(a) *Gasoline* (b) Kerosene
   (c) Light oil (d) Heavy oil
9. The process in which the octave rating of gasoline can be increased is called:
   (a) Cracking (b) Refining
   √(c) *Reforming* (d) Isomerism
10. A series of compounds, in which each member differs from the preceding one by a constant ratio of (>$CH_2$) methylene group is called:
    (a) Monologous series √(b) *Homologous series*
    (c) Isomerism (d) None of these
11. Isomerism in which the compounds possess the same molecular formula but different arrangement of carbon atoms in the hydrocarbon chain is called:
    √(a) *Chain isomerism* (b) Function isomerism
    (c) Position isomerism (d) Metamerism
12. A process that breaks large molecules into smaller one is called:
    (a) Refining (b) Reforming
    √(c) *Cracking* (d) None of these
13. Compounds which contain only carbon and hydrogen elements are called:
    (a) Carbohydrates √(b) *Hydrocarbons*
    (c) Halides (d) None of these
14. The hydrocarbons which contain one or more double or triple bonds are called:
    (a) Saturated hydrocarbons √(b) *Unsaturated hydrocarbons*
    (c) Paraffin (d) Halogens

15. The first member of alkene series is:
(a) Methane (b) Ethane
√(c) *Ethene* (d) Ethyne

16. The hydrocarbons in which carbon atoms are arranged in rings are called:
(a) Aliphatic (b) Aromatic
√(c) *Alicyclic* (d) None of these

17. The quality of petrol is measured by:
(a) Cracking (b) Reforming
√(c) ***Octane number*** (d) Decane number

18. General formula for alkane is:
√(a) $C_nH_{2n+2}$ (b) $C_nH_{2n}$
(c) $C_nH_{2n-2}$ (d) $C_nH_{2n+1}$

19. The first member of Alkyne series is:
(a) Methane (b) Ethane
(c) Ethene √(d) ***Acetylene***

20. The number of isomers of butane is:
(a) 1 √(b) 2
(c) 3 (d) 4

21. An atom or group of atoms present in a molecule and is responsible for chemical behaviour is called:
(a) Alkyl group (b) Alkenyl group
√(c) ***Functional group*** (d) Aryl group

22. Iso-butane possesses:
(a) Position isomerism (b) Functional isomerism
(c) Metamerism √(d) ***Chain isomerism***

23. Preparation of ethene form Ethyl Alcohol is an example:
√(a) ***Dehydration*** (b) Hydration
(c) Dehalogenation (d) Halogenation

24. The Hydrocarbons which possess double bond in their molecules are called:
(a) Alkanes √(b) ***Alkenes***
(c) Alkynes (d) Paraffins

25. The alkanes are also called:
(a) Olefins (b) Alkynes
√(c) ***Paraffins*** (d) Acetylenes

26. Which is the functional group of alcohols:
(a) -X (b) -COOH
√(c) *-OH* (d) $>C=O$

27. Which of the following molecules is alkane:
(a) $C_5H_8$ (b) $C_5H_{10}$
√(c) $C_5H_{12}$ (d) $C_5H_{14}$

28. Methane is also known is:
(a) Oil gas (b) Kerosene
(c) Gasoline √(d) *Marsh gas*

SESSION
2016-2017

# CLASS-IX

# CHEMISTRY

## Chapter # 18

## CHEMICAL INDUSTRIES

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# CHEMICAL INDUSTRIES 18

## INTRODUCTION:

Chemical industries are generally established in the country to get variety of useful and profitable products on large scale from the raw materials which are available in the country, through chemical processing. Hence the industry where useful products or chemical compounds are produced is called chemical industry.

The other daily useful products are soaps, detergents, plastics, paints, varnishes, polishes and inks. Apart from that the rising need of food with the population growth round the world, has made it necessary to preserve and store the food items. This need has therefore paved the way for the establishment of industries which serve the purpose of food preservation.

## SODA INDUSTRIES:

The term soda industries relates to the products manufactured from **sodium** compounds i.e. **caustic soda** [sodium hydroxide or NaOH], **soda ash** [anhydrous sodium carbonate or $Na_2CO_3$], **baking soda** [sodium bicarbonate or $NaHCO_3$] **washing soda** [decahydrated sodium carbonate or $Na_2CO_3 \cdot 10H_2O$] etc.

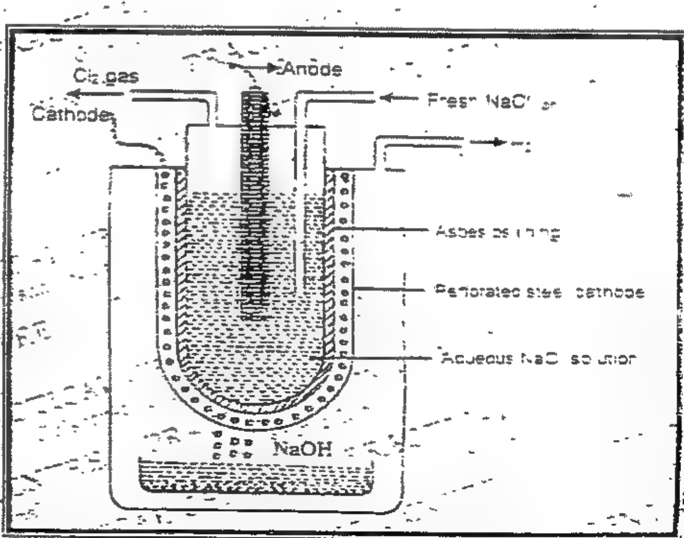
## PREPARATION of SODIUM HYDROXIDE (NaOH) [Caustic Soda]

**Sodium hydroxide** (NaOH) is one of the most important chemicals of industrial use. It is commonly called **caustic soda**, because it is corrosive to touch and causes harmful burns.

### (i) FROM NELSON'S CELL:

**Construction:**

Nelson's cell consists of a U-shaped perforated steel vessel, which acts as cathode. The graphite anode is dipped in the salt solution in the middle of U-shaped vessel. The U-shaped tank is separated from anode by asbestos lining or diaphragm. Through the asbestos lining, the salt solution slowly flows. The U-tube is known as anode compartment and this U-tube is fixed in an outer compartment, known as cathode compartment.



**Working:**

On passing electric current through the salt (NaCl) solution, **Chlorine** gas ($Cl_2$) is produced at **anode**, which rises into the dome at the top of the anode and then collected in the separate containers. **Sodium (Na)** metal is produced at **cathode** and then reacts with water of the solution flowing through the asbestos lining to release hydrogen ($H_2$) gas with the formation of sodium hydroxide **(NaOH)** solution which is collected at the bottom of the cathode compartment.

Following reactions take place in the cell:

**Ionization reaction:**

$$2NaCl_{(s)} \xrightleftharpoons{H_2O} 2Na^+_{(aq)} + 2Cl^-_{(aq)}$$

**Reaction at anode:**

$$2Cl^-_{(aq)} \longrightarrow Cl_{2(g)} + 2e^-$$

**Reaction at cathode:**

$$2Na^+_{(aq)} + 2e^- \longrightarrow 2Na_{(s)}$$

$$2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$$

## (ii) FROM CASTNER-KELLNER'S CELL:

**Construction:**

This cell is consisted of two compartments as shown in the figure. The upper compartment has **mercury** at the **bottom** of the cell which acts as **cathode. Brine** (Saturated solution of NaCl) is poured in this cell. **Anodes** are **titanium** plates dipped in the brine. There is also a lower compartment known as **Soda cell** or **denuder** which is packed with graphite blocks.

**Working:**

On passing electric current **chlorine gas** is released at **anodes** and is collected outside the anodes. $Na^+$ ions are discharged at **cathode** and form sodium amalgam (a mixture of Sodium metal with Mercury).

**Ionization reaction:**

$$2NaCl_{(s)} \xrightleftharpoons{H_2O} 2Na^+_{(aq)} + 2Cl^-_{(aq)}$$

**Reaction at anode:**

$$2Cl^-_{(aq)} \longrightarrow Cl_{2(g)} + 2e^-$$

**Reaction at cathode:**

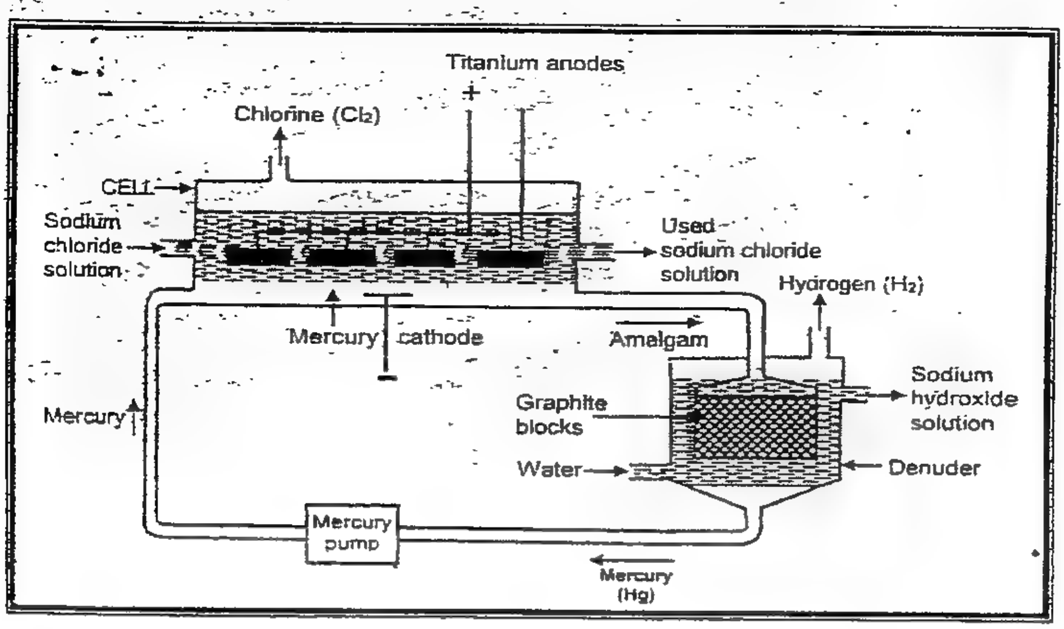
$$2Na^+_{(aq)} + 2e^- \longrightarrow 2Na_{(s)}$$

$$2Na_{(s)} + 2Hg_{(l)} \longrightarrow 2Na\,Hg \text{ (sodium amalgam)}$$



Sodium amalgam is then sent to **soda cell** where it reacts with water to produce NaOH solution and $H_2$ gas while free mercury is recycled and then sent back to the upper cell.

$$2Na/Hg_{(l)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(g)} + 2H_{2(g)} + 2Hg_{(l)}$$




## PHYSICAL PROPERTIES of SODIUM HYDROXIDE (NaOH):

(i) It is white crystalline and hygroscopic solid.

(ii) It melts at 318°C to a clear liquid and decomposes at 322°C.

(iii) Its density is $2.13\ g/cm^3$.

(iv) It is highly soluble in water and liberate large amount of heat.

## CHEMICAL PROPERTIES (REACTIONS):

### (i) Reaction with Acids:

It reacts with acids like sulphuric acid ($H_2SO_4$), hydrochloric acid (HCl) and nitric acid ($HNO_3$) to form corresponding salts of sodium.

$$2NaOH_{(aq)} + H_2SO_{4(aq)} \longrightarrow \underset{\text{Sodium sulphate}}{Na_2SO_{4(aq)}} + 2H_2O$$

$$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow \underset{\text{Sodium chloride}}{NaCl_{(aq)}} + H_2O$$

$$NaOH_{(aq)} + HNO_{3(aq)} \longrightarrow \underset{\text{Sodium nitrate}}{NaNO_{3(aq)}} + H_2O_{(l)}$$

### (ii) Reaction with Metals:

Sodium hydroxide reacts with certain metals like zinc, tin, aluminum. etc. then hydrogen gas is liberated with the formation of salt.

$$2NaOH_{(aq)} + Zn_{(s)} \xrightarrow{\text{heat}} \underset{\text{Sodium zincate}}{Na_2ZnO_{2(aq)}} + H_{2(g)}$$

$$2NaOH_{(aq)} + Al_{(s)} + 2H_2O_{(l)} \longrightarrow \underset{\text{Sodium aluminate}}{2NaAlO_{2(aq)}} + 3H_{2(g)}$$

### (iii) Reaction with Ammonium Chloride:

When NaOH reacts with ammonia salt i.e. ammonium chloride, it librates ammonia gas on warming.

$$NaOH_{(aq)} + NH_4Cl_{(aq)} \longrightarrow NaCl_{(aq)} + NH_{3(g)} + H_2O_{(l)}$$

### (iv) Reaction with Carbon Dioxide:

It reacts with carbon dioxide to produce **sodium carbonate** and **water**.

$$2NaOH_{(aq)} + CO_{2(g)} \longrightarrow \underset{\text{Sodium carbonate}}{Na_2CO_{3(aq)}} + H_2O_{(l)}$$

### (v) Reaction with Chlorine gas:

The reaction of sodium hydroxide with chlorine gas results in the formation of **sodium salt of oxy acids such as**, Sodium oxychloride (NaOCl) and Sodium chlorate ($NaClO_3$)

$$2NaOH_{(aq)} + Cl_{2(g)} \longrightarrow \underset{\text{Sodium chlorate (I)}}{NaOCl_{(aq)}} + NaCl_{(aq)} + H_2O$$

$$6NaOH + 3Cl_2 \xrightarrow{\text{heat}} \underset{\text{Sodium chlorate (V)}}{NaClO_3} + 5NaCl + 3H_2O$$

## Uses of Sodium Hydroxide:

(i) It is used in purification of bauxite.

(ii) It is used in manufacture of artificial silk.

(iii) It is used in textile and paper industries.

(iv) It is used in the manufacture of soap and petroleum industry.

(v) It is used in bleaching and dyeing process as well as for mercerizing the cotton cloth.

## INDUSTRIAL PREPARATION OF WASHING SODA ($Na_2CO_3$). $10H_2O$

Washing soda is commercially prepared by Ammonia-Solvey process or ammonia soda process.

## RAW MATERIALS:

The raw materials are:

1. Lime stone ($CaCO_3$) 2. Sodium Chloride (NaCl)

3. Ammonium Chloride ($NH_4Cl$) 4. Carbon dioxide ($CO_2$)

The industrial process involves the following steps:

**STEP 1:**

Lime stone ($CaCO_3$) is heated to yield calcium oxide (quicklime CaO) and the $CO_2$ gas.

$$CaCO_{3(s)} \xrightarrow{\Delta} CaO_{(s)} + CO_{2(g)}$$

**STEP 2:**

The ammonia ($NH_3$) is used as a raw material in this step. is recovered by reacting CaO with $NH_4Cl$.

$$2NH_4Cl_{(aq)} + CaO_{(s)} \longrightarrow 2NH_{3(g)} + CaCl_{2(aq)} + H_2O_{(l)}$$

**STEP 3:**

This ($CO_2$) is passed into aqueous solution of ammonia, and the ammonium bicarbonate is produced.

$$NH_{3(g)} + CO_{2(g)} + H_2O_{(l)} \longrightarrow NH_4HCO_{3(aq)}$$

**STEP 4:**

Ammonium bicarbonate ($NH_4HCO_3$) reacts with aqueous cold solution of sodium chloride ($NaCl$) at 15°C, called **Brine** to yield, sodium bicarbonate ($NaHCO_3$), which is not soluble at low temperature (15°C) and this precipitates out.

$$NaCl_{(aq)} + NH_4HCO_{3(aq)} \xrightarrow{\text{At } 15^\circ C \text{ brine}} NH_4Cl_{(aq)} + NaHCO_{3(s)}$$

**STEP 5:**

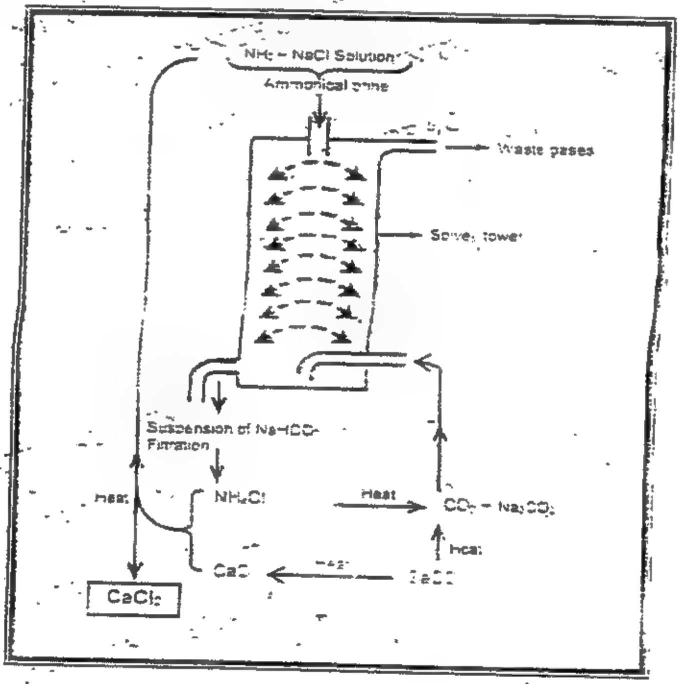
Sodium bicarbonate ($NaHCO_3$) on heating yields sodium carbonate ($Na_2CO_3$).

$$2NaHCO_{3(s)} \xrightarrow{\Delta H} Na_2CO_{3(s)} + H_2O_{(l)} + CO_{2(g)}$$

**STEP 6:**

Anhydrous sodium carbonate ($Na_2CO_3$) is known as **soda-ash** and sodium carbonate decahydrate ($Na_2CO_3 . 10H_2O$) is commonly known as **washing soda**.

$$Na_2CO_3 + 10H_2O \xrightarrow{\text{heat}} Na_2CO_3.10H_2O$$




## PHYSICAL PROPERTIES

| Sodium Bicarbonate $NaHCO_3$ | Sodium Carbonate $Na_2CO_3$ |
|---|---|
| It is a white crystalline solid | It is a white amorphous solid |
| It is little sweet in taste | It is bitter in taste |
| Its density is 2.1g $cm^3$ | Its density is 2.3g $cm^3$ |
| It is sparingly soluble in water at room temperature | It is fairly soluble in water at room temperature with evolution of heat |

## USES OF SODIUM BICARBONATE or BAKING SODA ($NaHCO_3$):

1. Sodium Hydrogen carbonate (sodium bicarbonate) is used as baking powder.
2. It is used in the preparation of effervescent drinks and fruit salts.
3. It is used in medicines to remove acidity in stomach as anti-acid (antacid).
4. It is used in fire extinguishers.

## USES OF SODIUM CARBONATE ($Na_2CO_3$):

1. It is used as cleaning agent in soap and detergent.
2. It is used to make ordinary glass which is used to make bottles.
3. It is used in manufacturing of papers, cement and paints.
4. Hard water is changed into soft water by adding sodium carbonate ($Na_2CO_3$) which forms insoluble Calcium Carbonate ($CaCO_3$) and Magnesium Carbonate ($MgCO_3$).

$$CaCl_{2(aq)} + Na_2CO_{3(aq)} \longrightarrow CaCO_{3(s)} + 2NaCl_{(aq)}$$

$$MgCl_{2(aq)} + Na_2CO_{3(aq)} \longrightarrow MgCO_{3(s)} + 2NaCl_{(aq)}$$

## CHEMICAL PROPERTIES of SODIUM BICARBONATE ($NaHCO_3$)

### (i) Action of heat (Decomposition):

Sodium bicarbonate loses carbon dioxide and water to give sodium carbonate on heating.

$$2NaHCO_{3(s)} \xrightarrow{heat} Na_2CO_{3(s)} + H_2O_{(l)} + CO_{2(g)}$$

### (ii) Reactions with acids:

Sodium bicarbonate reacts with acids such as hydrochloric acid to form its salt (sodium chloride) with the liberation of carbon dioxide gas.

$$NaHCO_{3(s)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)} + CO_{2(l)}$$

## CHEMICAL PROPERTIES of SODIUM CARBONATE ($Na_2CO_3$)

### (i) Reactions with Acids:

Sodium carbonate reacts with acids then carbon dioxide is evolved.

$$Na_2CO_{3(s)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

$$Na_2CO_{3(s)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$$

### (ii) Reaction with Less Electropositive Metals salt:

It forms carbonates of non-alkali metal salts such as magnesium chloride ($MgCl_2$) and zinc sulphate ($ZnSO_4$).

$$Na_2CO_{3(aq)} + MgCl_{2(aq)} \longrightarrow MgCO_{3(s)} + 2NaCl_{(aq)}$$

$$Na_2CO_{3(aq)} + ZnSO_{4(aq)} \longrightarrow ZnCO_{3(s)} + Na_2SO_{4(aq)}$$

### (iii) Reaction with Carbon Dioxide:

Aqueous sodium carbonate reacts with carbon dioxide to give sodium bicarbonate.

$$Na_2CO_{3(aq)} + H_2O_{(l)} + CO_{2(g)} \longrightarrow 2NaHCO_{3(s)}$$

### (iv) Fusion with Sand:

Sodium carbonate reacts with sand (silicon dioxide, $SiO_2$) at very high temperature untill they melt then Sodium Silicate ($Na_2SiO_3$) i.e. water glass is formed.

$$Na_2CO_{3(s)} + SiO_{2(s)} \xrightarrow[\text{fusion}]{} Na_2SiO_{3(s)} + CO_{2(g)}$$

## HYDRATED SODIUM CARBONATE. $Na_2CO_3 . 10H_2O$ (Washing Soda):

### PREPARATION:

When calculated amount of water is added in soda ash ($Na_2CO_3$) then it crystallizes into decahydrated sodium carbonate ($Na_2CO_3 . 10H_2O$).

$$Na_2CO_3 + 10H_2O \longrightarrow Na_2CO_3.10H_2O_{(s)}$$

Sodium carbonate decahydrate ($Na_2CO_3 . 10H_2O$) is commonly known as washing soda which is used for washing purposes.

## SOAPS:

The sodium and potassium salts of fatty acids used for cleansing purpose are called soaps. The acid components employed are usually stearic acid, $C_{17}H_{35}COOH$; oleic acid, $C_{17}H_{33}COOH$ and palmitic acid, $C_{15}H_{31}COOH$.

### Raw Material:

(i) The Natural source of the above fatty acids is either vegetable oils such as coconut oil, palm oil or animal fats such as beef tallow.

(ii) The alkali metal (sodium and potassium) sources are sodium hydroxide (NaOH) and potassium hydroxide (KOH).

## PREPARATION OF SOAP (SAPONIFICATION):

When beef tallow (tristerin) reacts with sodium hydroxide then soap (sodium stearate) is formed along with **glycerol (glycerin)**. Now aqueous solution of sodium chloride is added in this mixture where Glycerol (Glycerin) is dissolved in the salt solution. Glycerol (Glycerin) is heavier than soap so it settled down and drained off from the bottom of the container. This process is known as salting out the soap.

The chemical process for the preparation of soap is called Saponification. The reaction is represented by the following equation.

$$\begin{array}{l} CH_2\ O_2\ CC_{17}\ H_{35} \\ | \\ CHO_2\ CC_{17}\ H_{35} + 3NaOH \xrightarrow{\text{heat}} \\ | \\ CH_2\ O_2\ CC_{17}\ H_{35} \\ \text{tristerin a glyceride} \end{array} \quad \begin{array}{l} CH_2OH \\ | \\ CHOH + 3C_{17}H_{35}CO_2Na \\ | \qquad\qquad \text{Soap (sodium stearate)} \\ CH_2OH \\ \text{glycerin} \end{array}$$

## TYPES OF SOAPS AND THEIR COMPOSITION:

### (i) Toilet Soaps:

Toilet soaps are prepared by using 80 to 90% animal fat (tallow) and 10 to 20% coconut oil. Animal fat consists of stearic and oleic acids. Palmitic acid is found in vegetable oils. The desired colour and perfumes are added in these soaps.

### (ii) Laundry Soaps:

Laundry soaps are prepared by using animal fats which is further heated with resin and caustic soda. During solidification, sodium silicate, washing soda and sodium phosphate are added to increase the cleansing ability of the soap. This type of soap is used for washing clothes.

### (iii) Kitchen Soaps:

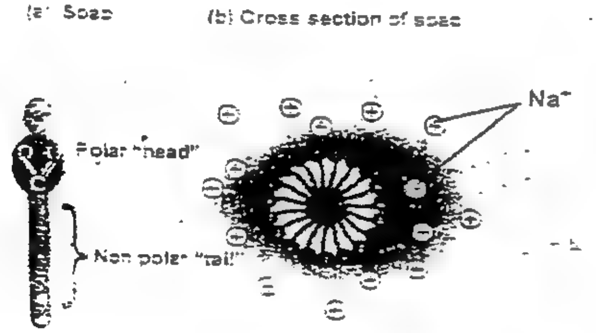
Kitchen soaps are prepared by using animal fats with sand, washing soda and caustic soda. This type of soap is used for washing and cleansing utensils.

### (iv) Shaving Soaps:

Shaving soaps are prepared by using good quality animal fats or edible oil with potassium hydroxide (caustic potash) and excessive amount of stearic acid which prevents drying the soap. This soap is used for shaving purposes.

## FUNCTION OF SOAPS:

Soaps remove dirt and stains. Dirt particles (on skin or cloth) become surrounded by layer of oil or fat. Water molecules are unable to disperse these greasy or oily stains but soap are able to separate and dissolve oily or greasy stains because the carboxylate part (hydrocarbon chain of soap) can dissolve the oily layer. The process is shown in the figure.




Soap molecule (a) A sodium soap molecule (b) Non polar (hydrophobic) hydrocarbon chains are clustered in the interior part and polar (hydrophilic) carboxylate groups are on the surface. Soap micelles repel each other because of their negative surface charges.

## DETERGENTS:

Detergents are soapless cleansing agents. They are the salts of sodium with organic sulphonic acids having general formula $R-SO_3^-Na$ or $R-O-SO_3^-Na$.

## COMPOSITION OF DETERGENTS:

The detergents consist of two parts: a hydrocarbon and a **sulphonate** ($-SO_3^-$) or a sulphate ($-OSO_3^-$) group. These molecules are made usable by converting them into water soluble sodium salts.

A simple example of these compounds is sodium lauryl sulphate, $C_{12}H_{25}OSO_3Na^+$, a sodium salt of a long chain hydrocarbon attached to a sulphate group. The detergents available having this composition are usually used for washing a variety of utensils.

The detergents closely related to soaps and used for household laundry belong to the sulphonates such as sodium –p-dodecyl benzene sulphonate. The structure of such molecule contains a benzene ring between sulphonate and alkyl group.

The detergents of this type are used for washing various kinds of clothes.

## FUNCTION OF DETERGENTS:

Function of detergents is same as soaps. They offer an advantage over soaps by functioning well in hard water, [water containing calcium ($Ca^{2+}$), ferrous ($Fe^{2+}$), ferric ($Fe^{3+}$) and magnesium ($Mg^{2+}$) ions]. There is a large variety of detergents which are used as washing powders and washing liquids.

## PLASTICS:

Plastics are one of the types of polymers. The compounds built up of a large number of smaller molecules that have reacted with one another are called **polymers.** Polymers occur in nature as well as synthesized. Plastics belong to the synthetic polymers. The essential ingredients of these compounds are organic substances of various types.

## SOURCES:

The common raw materials for making plastics are: petrochemicals, cotton, wood, gas, coal, salt and water.

## APPLICATIONS:

Plastics have a large number of applications because of their toughness, water resistance, corrosion resistance, ease of fabrication and remarkable colour range.

## CLASSIFICATION:

(a) Thermoplastic (b) Thermosetting plastics

## (a) THERMOPLASTIC:

The synthetic plastic which **can be shaped again and again** is called thermoplastic. It is obtained by addition polymerization.

They become soft on heating and hard on cooling. The repetition of the process does not affect the properties of these types of plastics. They can easily be molded into various shapes.

e.g. Cellulose nitrate, cellulose acetate, vinyl chloride polymers are the examples of this class.

## (b) THERMOSETTING PLASTICS:

The synthetic plastic which **can't be shaped again and again** is called thermosetting plastic.

This kind of plastics can only heated once before they set on cooling. The process cannot be repeated in this case as they do not soften on reheating.

e.g. Phenol and formaldehyde give bakelite: epoxy resins (araldite and adhesive) are the examples of this class.

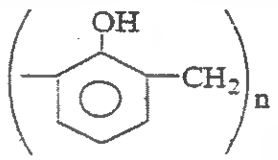
## STRUCTURE AND USES OF SOME COMMON PLASTICS:

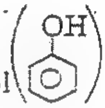
(a) **Polythene (Polyethylene):** $(-CH_2-CH_2-)_n$

It is an **addition polymer** of ethene (ethylene) ($CH_2 = CH_2$) most commonly used in the preparation of polythene bags for carrying fruits, vegetables and plastic bottles for drink and juices, etc.

(b) **Polyvinyl chloride (PVC):** $(-CH_2-\underset{}{\overset{Cl}{\overset{|}{C}H}})_n$

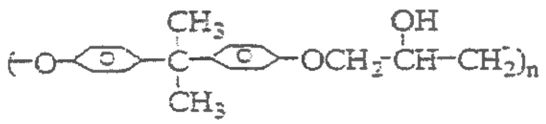
It is an **addition polymer** of vinyl chloride ($CH_2 = CHCl$) used in the manufacture of electrical cable coverings, suit cases, gramophone, etc.

(c) **Bakelite (Phenol-formaldehyde polymer)** 

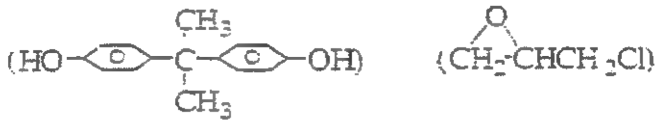
It is a **condensation polymer** of formaldehyde (HCHO) and phenol 

It is used in the manufacture of switches, electric board sheets, cameras, radio, telephone components.

(d) **Epoxy resin:**



It is a condensation polymer of biphenol A and epichlorohydrin.



A well known adhesive **araldite** is an example of this plastic material.

## PAINTS:

Paints are fluids containing a colouring material (pigments) dispersed in organic liquid. They apply onto a surface of walls, windows, doors, wooden and iron furniture, etc. On exposure to the air till dryness it changes to hard adherent protective and decorative layer. Paints may either be oil based or water based.

## COMPOSITION OF OIL PAINTS OR ENAMELS:

The oil based paint is composed of following main components:

Linseed oil, colour pigments, a thinner, a resin and a drier.

The linseed oil serves as a protective layer on the painted surface. Pigments provide colours. A thinner is turpentine or other volatile liquid. The resins act as binders. A drier accelerates drying or hardening of linseed oil. Fillers such as china clay and barium sulphate ($BaSO_4$) are added to the pigments to increase the durability of paints.

These types of paints are usually called **oil paints** or synthetic **enamels** and are applied over wooden or iron surface.

# COMPOSITION OF WATER PAINTS OR DISTEMPER:

Water based paints are available in the form of emulsion. Such paints usually consist of an emulsion of hydrocarbons, butadiene and styrene, polymers polyvinyl acetate or acrylic resins in water.

The pigments used as colouring material are usually titanium dioxide ($TiO_2$), zinc sulphate ($ZnSO_4$) and barium sulphate ($BaSO_4$) for white, carbon black (C) for black colour, chrome yellow ($PbCrO_4$) for yellow colour, oxides of iron, $Fe_2O_3$ for red and FeO for brown; chromium oxide ($Cr_2O_3$) for green etc.

These types of paints are usually called **distemper** and are applied over walls especially the interior ones.

# VARNISH:

Varnish is a clear solution and consists of resins, volatile organic solvent and driers without pigments used as a protective and decorative coating for various wooden or metallic surfaces.

# APPLICATION:

When applied on a surface, varnish dries to a tough adherent film by the drying oil (linseed oil) which undergoes evaporation, oxidation and polymerization.

Varnishes are used without pigments therefore these are less resistant to damage by light than paints. The transparent film furnished by varnishes accentuates the texture of the surface coated.

The component of varnishes are mostly comprised of synthetic alkyl and urethane resins because of their greater durability, less yellowing, ease of application and beauty. Alkyl resins are formed by the reaction of polyhydric alcohols and polybasic acids. **Urethane resins are ethyl carbonate molecules.**

# POLISHES:

A protective layer upon the surfaces of certain articles such as shoes, furniture, cars, motorcycles, floor of the houses etc is called **Polish.**

Here the polishes meant only for applying on the shoes are described such as black shoe and dark brown shoe polishes.

# COMPOSITION OF BLACK SHOES POLISH:

The black shoes polish is consisted of **powdered animal charcoal**, bees wax, carnauba wax, turpentine oil, nigrosine oil, sodium hydroxide and soap.

# COMPOSITION OF DARK BROWN POLISH:

The dark brown shoe polish is mainly made up of **Bismarck brown, pearl ash (potassium carbonate)**, bees wax, carnauba wax, turpentine oil, nigrosine oil, sodium hydroxide and soap.

# FUNCTIONS OF THE COMPONENTS OF POLISH:

**Animal charcoal** gives black while **Bismarck brown** gives dark brown colour to the polishes. The waxes maintain the required softness and provide shine to the shoes. Turpentine oil besides keeping the shoes soft, prevent them from drying and helps in the absorption of the polish in leather from which shoes are manufactured.

# PREPARATION OF SHOES POLISH:

Pure bees wax is melted by heating on the water bath. Soon after that turpentine oils is added to it. The mixture is homogenized and cooled with stirring. Meanwhile in another container caustic soda (NaOH) is heated in a minimum quantity of water to make a viscous alkaline solution (lye). This viscous solution is added to the above mixture with vigorous stirring. When it becomes thick, nigrosine oil is added to it and stirring is continued till it gains the desired thickness.

A powdered **animal charcoal** is added to get the black colour polish.

**Bismarck brown and pearl ash** (potassium carbonate) is added to get brown colour polish.

## INKS:

Inks are deeply coloured liquids of various composition used for writing or printing purposes. They contain a protective substance such as gum to make them more durable.

## TYPES OF INKS:

The inks of different colours are made for various purposes which are given below along with their components:

### i) Black ink:

It is a mixture of Gallic acid (obtained from the oak plant), Tannic acid, Gum arabic, Ferrous sulphate, Hydrochloric acid and Phenol blue.

### ii) Blue ink (Royal blue):

It is a mixture of Carboxy-methyl cellulose, Methyl violet, Ethylene glycol, Phenol and Acetone.

### iii) Red ink:

It is prepared normally from Brazil wood or by dissolving carmine in aqueous ammonium hydroxide. The eosin is also used as a constituent of red ink.

### iv) Marking ink:

It consists of silver nitrate solution coloured and thickened with gum or dyes.

### v) Printing inks:

These are made by a pigment into a suitable varnish medium with driers and appropriate accessories. For printing of good quality a polymerized linseed oil is generally used together with resin oil and various pigments. The pigment is usually ground finely in a mixture of mineral oil and resins.

### vi) Type writing inks:

These are prepared by employing dyes in conjunction with the other materials which include certain proportion of glycerol.

### vii) Stamp pad ink:

It is prepared with aniline dye, glycerin, tug, soybean oil, water and alcohol.

## PREPARATION OF BLACK INK:

Tannic acid (75g) and gallic acid (20g) are dissolved in 150cm$^3$ of warm water. In another container ferrous sulphate (100g) along with gum arabic (60g) is dissolved in 600cm$^3$ of distilled water. Mix the two solutions by adding 75ml of dilute hydrochloric acid (15g), phenol blue (15g) and water is added to produce 3dm$^3$ solution. The contents to be kept aside for a week and then filtered.

## PREPARATION OF BLUE INK:

First of all the carboxy methyl cellulose is dissolved in minimum quantity of distilled water. In another pot, methyl violet (5g) is dissolved in 200cm$^3$ warm distilled water and the solution is filtered. This solution is mixed with the carboxy methyl cellulose solution and the remaining ingredients i.e. Ethylene glycol (20cm$^3$), acetone (10cm$^3$) and phenol (1g) are added. The solution to be stirred well and kept for 10 days. Afterwards it filtered to get the royal blue ink ready for use.

## CAUSES OF FOOD SPOILAGE:

Following are the causes of food spoilage:

### (i) Moisture:

The agricultural products of low moisture contents such as corn and soybean when exposed to higher humidity take up enough moisture contents to permit the growth of ***moulds*** and ***bacteria***.

### (ii) Microbiological (Microbes) activities:

There are several kinds of food which tend to spoil by microbe attack. Fish, poultry and dairy products are specifically spoiled by microbes' growth.

### (iii) Chemical Changes (Enzymes):

The chemical changes are established by enzymes are responsible for food spoilage. These enzymes may be produced by yeast and bacteria which contaminate the product. The chemical changes rancidify the butter into sour taste similarly milk changes into curd.

## FOOD PRESERVATION METHODS:

There are numerous methods of preservation of foods. Some of the most widely used ones are described below.

### (a) Removal of moisture:

This method of preservation of food relates with removal of water or drying process. The products that need to be dried are the various pastes, milk, coffee and tea, spices, etc.

### (b) Addition of salt and sugar:

This method of preservation of food relate with adding sugar and salt to many sausages to increase their shelf life. The sugar and salt bind the water which retards the growth of microorganisms.

***The water binding agents are known as HUMECTANTS.***

### (c) Temperature control:

This method of preservation of food relates with the freezing of foods because of low temperature also retards the growth of microorganisms.

### (d) Preservation by Storage:

Many types of fresh foods such as fruits, vegetables, meats, fish, etc. when required to be stored for long term by following various methods:

| (i) CANNING | (ii) IRRADIATION |
|---|---|
| The preservation of food by sealing it into air tight containers is called canning.<br>This method is widely used for food preservation. The containers may be metal which as often plastic-lined aluminum or special strength glass.<br>The raw food is packed into the container sealed and the whole package is then treated with heat in a steam pressure used to cook the food and sterilize both the container and the contents. | The process of passing the radiation through any substance is called irradiation.<br>The radiation is comprised of alpha ($\alpha$), beta ($\beta$) and gamma ($\gamma$) rays.<br>Radiation can be used to preserve food such as meat, potatoes and onions, etc. without causing undesirable protein denaturizing or appreciably altering the taste.<br>The process leaves no residual radioactivity in the food. There is a little loss of vitamins in all foods by the recommended doses than that seen with canning, freezing or drying. |

# EXERCISE

**Fill in the blanks:**

(i) Sodium hydroxide causes harmful burns to the skin; therefore it is commonly called ***Caustic soda.***

(ii) Sodium hydroxide gives ***sodium and hydroxide ions*** when dissolved in water.

(iii) When sodium hydroxide is treated with ***sulphuric acid*** it forms sodium sulphate salt.

(iv) The reactions of sodium hydroxide with ***certain metals*** result in liberation of hydrogen gas.

(v) The molecular formula for baking soda is $NaHCO_3$.

(vi) Sodium carbonate, washing soda and ***baking soda*** are generally prepared by Ammonia Solvay process.

(vii) The chemical process for the preparation of soap is called ***saponification.***

(viii) The detergents are usually consists of two parts, ***hydrocarbons*** and sulphonate or sulphate.

(ix) Compounds made up of large number of smaller molecules are called ***polymers.***

(x) The plastics belong to ***thermosetting plastics*** class can only be heated once before they set on cooling.

(xi) P.V.C is the abbreviation (Short form) for ***poly vinyl chloride.***

(xii) Paints are fluids containing ***pigments*** dispersed in organic liquid.

(xiii) Linseed oil, pigments, resin etc are main components of ***oil*** paints.

(xiv) A thinner is turpentine or other ***organic*** liquid.

(xv) Water based paints are available in the form of ***emulsion.***

(xvi) ***Varnishes*** are used without pigments to furnish the transparent film on the surface coated.

(xvii) Marking ink consists of ***silver nitrate*** solution thickened with gum or of dyes.

(xviii) The removal of moisture controls the growth of ***moulds and bacteria*** which renders the food to spoil.

(xix) The water binding agents used in the preservation of food are known as ***humectants.***

(xx) The preservation of food by sealing into tight containers is called ***canning.***

(xxi) ***Baking soda*** is used in the preparation of effervescent drinks and fruit salts.

(xxii) Sodium carbonate when fused with ***sand*** it forms sodium silicate (glass).

(xxiii) ***Washing soda*** is used for softening hard water.

(xxiv) The colour of black shoe polish is due to ***animal charcoal.***

(xxv) Turpentine oil besides keeping the shoes ***soft*** prevent than from drying and helps in is absorption in the leather.

**Tick the correct answers:**

(1) Sodium hydroxide is prepared at large scale by the following methods.
√(a) *Electrolytes process* (b) Saponification method
(c) Hydrolysis

(2) Sodium hydroxide at 318°C:
(a) Melts with decomposition (b) Does not melt
√(c) *Melts to a clear liquid* (d) Converts to gas

(3) Carbon dioxide and sodium hydroxide react to give.
√(a) *Sodium carbonate and water* (b) Sodium carbonate only
(c) Sodium metal and water (d) Sodium and carbon monoxide

(4) When sodium hydroxide reacts with ammonium chloride it liberates gas.
(a) Carbon dioxide (b) Hydrogen
(c) Oxygen √(d) *Ammonia*

(5) Sodium hydrogen carbonate used in medicine which of the effects it causes in the stomach?
(a) Increase the basicity (b) Increase the acidity
√(c) *Neutralize the acidity* (d) Decrease the basicity

(6) The product / products obtained by reaction of sodium carbonate with carbon dioxide in aqueous medium is / are:
(a) Sodium hydroxide √(b) *Sodium hydrogen carbonate*
(c) Sodium carbonate and water (d) Sodium oxide

(7) Carbonate and bicarbonate of sodium are manufactured by:
(a) Contact method √(b) *Ammonia Solvay process*
(c) Ostwald's process (d) Haber's method

(8) Detergents are cleansing agents prepared form:
(a) Water soluble sodium salts (b) Hydrocarbons only
√(c) *Hydrocarbon and a sulphonate* (d) Sulphonate only

(9) The material which softens on heating and hardnes on cooling come under the class:
(a) Thermosetting plastic √(b) *Thermoplastic*
(c) Formica (d) Bakelite

(10) The class of plastic that can only be heated once before they set on cooling is:
(a) Thermoplastic (b) Cellulose nitrate
(c) Cellulose acetate √(d) *Thermosetting plastic*

(11) The polymer which is used in the manufacture of bags for shopping purpose is.
(a) Poly vinyl chloride √(b) *Poly ethylene*
(c) Epoxy resin (d) Araldite

(12) Cameras, radios, telephone sets, etc are prepared form:
(a) Polyethene (b) Poly vinyl chloride
√(c) *Bakelite* (d) Cellulose nitrate

(13) The pigments used to produce white colour are:
(a) Oxides of iron (b) Chromium oxide
√(c) *Zinc sulphate* (d) Ferric oxide

(14) Varnishes are used:
(a) With pigments (b) Without driers
√(c) *Without pigments* (d) Without resins

(15) Which of the following constituents of shoe polish is used to provide shining to the shoes?

√(a) ***Bees wax*** (b) Sodium hydroxide

(c) Pearl ash (d) Soap

(16) The common ingredients used in black and brown shoe polishes is:

√(a) ***Nigrosine oil*** (b) Pearl ash

(c) Animal Charcoal (d) none of them

(17) A mixture of infusion of gall nuts with ferrous sulphate and certain proportion of hydrochloric acid produces:

√(a) ***Black ink*** (b) Printing ink

(c) Marking ink (d) Blue ink

(18) Red ink is normally prepared from:

(a) Oak plant (b) Linseed oil

(c) Silver nitrate √(d) ***Brazil wood***

(19) Addition of salts and sugar:

(a) Decreases the shelf life of food √(b) ***Preserve the food***

(c) Spoil the food (d) Help to grow micro-organisms

(20) The radiation paned through food to preserve it is comprised of:

(a) $\alpha$-rays only (b) $\gamma$-rays

(c) $\alpha$ and $\beta$-rays only √(d) ***$\alpha$, $\beta$ and $\gamma$-rays***

**Answer the following questions:**

(1) (a) Give the industrial preparation of sodium hydroxide.

(b) Give the reaction of NaOH with.

(i) HCl (ii) Al (iii) $CO_2$ (iv) $NH_4Cl$ (v) $Cl_2$

(c) Describe the uses of NaOH.

(2) (a) Describe Ammonia Solvay process for the manufacture of sodium hydrogen carbonate.

(b) Complete the following reactions:

(i) $NH_4Cl + Ca(OH)_2 \longrightarrow$

(ii) $NaHCO_{3(s)} \xrightarrow{heat}$

(iii) $Na_2CO_3 + CO_2 + H_2O \longrightarrow$

(iv) $NaOH + CO_2 \longrightarrow$



(3) (a) What do you mean by saponification?

(b) What are different types of soap? And what is the function of soap?

(4) (a) What do you understand by a detergent? Give the composition of detergent and its function.

(b) Differentiate between thermoplastic and thermosetting plastic.

Describe the structures of some of the plastics.

(c) Describe composition and application of varnishes.

(5) (a) Differentiate between oil paints and water paints.

(b) What are polishes? Give in details about the composition and preparations of different types of polishes.

(c) Write notes on food preservation.